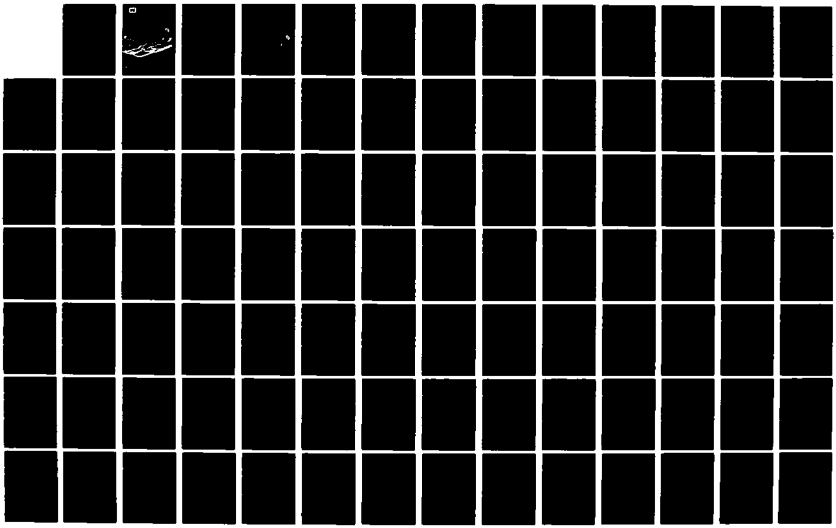
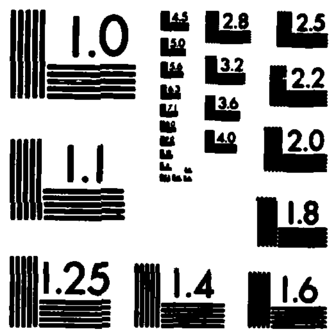
AD-A120 573 A LITERATURE SURVEY ON THE WETLAND VEGETATION OF ALASKA 1/3
(U) ALASKA UNIV FAIRBANKS INST OF ARCTIC BIOLOGY AND
MUSEUM A R BATTEN ET AL. AUG 82 WES-TR-Y-82-2

UNCLASSIFIED DACW39-76-M-2473 F/G 8/6 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

WETLANDS RESEARCH PROGRAM

TECHNICAL REPORT Y-82-2

A LITERATURE SURVEY ON THE WETLAND VEGETATION OF ALASKA

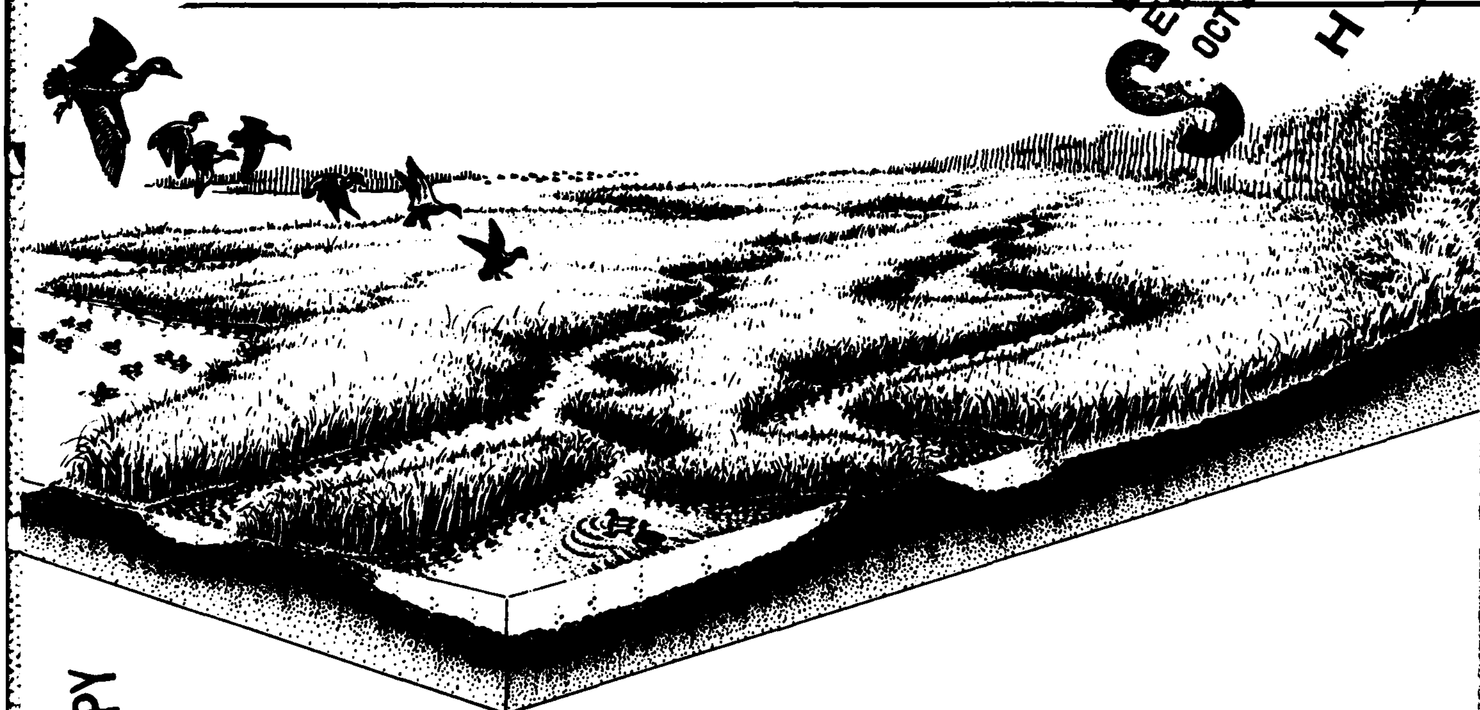
by

Alan R. Batten and David F. Murray

Institute of Arctic Biology and Museum
University of Alaska
Fairbanks, Alaska 99701

August 1982

Final Report



Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under Contract No. DACW39-76-M-2473

Monitored by Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Technical Report Y-82-2	2. GOVT ACCESSION NO. AD-A120 573	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A LITERATURE SURVEY ON THE WETLAND VEGETATION OF ALASKA		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Alan R. Batten David F. Murray		8. CONTRACT OR GRANT NUMBER(s) Contract No. DACW39-76-M-2473
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Alaska Institute of Arctic Biology and Museum Fairbanks, Alaska 99701		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Dredging Operations Technical Support Program
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE August 1982 13. NUMBER OF PAGES 232
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Alaska
Vegetation
Wetlands

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This literature survey contains published information on wetlands vegetation of Alaska prior to September, 1977. The literature review and summaries are organized under the broad habitat categories of: (a) freshwater wetlands (ponds and lakes, freshwater marshes, peatlands, streams, and riparian gravel bars and cutbanks), and (b) saline or brackish water wetlands (strands and supratidal meadows, saline or brackish marshes, and intertidal zones). The

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. ABSTRACT (Continued).

floristics and vegetation of these categories are discussed on a regional basis which includes Southeastern Alaska, Southcentral Alaska, Aleutian Islands, Bering Sea Islands, Bering Sea Mainland, Chukchi Sea, Beaufort Sea, and Interior Alaska.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

This report was prepared for the Office, Chief of Engineers, U. S. Army, as part of the wetlands regulatory research effort, Dredging Operations Technical Support (DOTS) Program, Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The major objective of wetlands regulatory research is to provide field personnel with technical data and methods that can assist them in the onsite geographic delineation of boundaries between aquatic, wetland, and nonwetland ecosystems.

The information discussed herein was collected under Contract No. DACW-39-76-M-2473 by the Institute of Arctic Biology and Museum, University of Alaska, Fairbanks, Alaska. The study was specifically directed toward compiling literature through August 1977 that pertains to vegetation found in Alaskan wetlands. The authors of the report were Mr. Alan R. Batten and Dr. David F. Murray.

Technical monitors of this study were Drs. Gary E. Tucker, EL, and Robert Terry Huffman, EL. Dr. Huffman also served as the Contracting Officer's Representative. Preparation of this report was under the general supervision of Drs. H. K. Smith, Chief, Wetland and Terrestrial Habitat Group, Environmental Resources Division (ERD), EL, and C. J. Kirby, Chief, ERD; Mr. C. C. Calhoun, Program Manager, DOTS; and Dr. J. Harrison, Chief, EL.

Commanders and Directors of WES during the conduct, preparation, and publication of this report were COL John L. Cannon, CE, COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

This report should be cited as follows:

Batten, A. R., and Murray, D. F. 1982. "A Literature Survey of the Wetland Vegetation of Alaska," Technical Report Y-82-2, prepared by Institute of Arctic Biology and Museum, University of Alaska, Fairbanks, Alaska, for the U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

TABLE OF CONTENTS

	Page
PREFACE	i
LIST OF FIGURES	vii
CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT	x
INTRODUCTION	1
WETLAND REGIONS	4
WETLAND CATEGORIES	8
SOUTHEASTERN ALASKA	21
References to Southeastern Alaskan Wetlands	23
Pond and lake	25
Fresh water marsh	27
Peatland	29
Stream	43
Riparian gravel bar and cutbank	44
Strand and supratidal meadow	44
Saline or brackish marsh	49
Intertidal zone	52
Succession in general	52
Vegetation maps	54
SOUTHCENTRAL ALASKA	55
References to Southcentral Alaskan Wetlands	57
Pond and lake	58
Fresh water marsh	60
Peatland	61
Stream	64
Riparian gravel bar and cutbank	65
Strand and supratidal meadow	65

Saline or brackish marsh 68

Intertidal zone 76

Vegetation maps 76

ALEUTIAN ISLANDS 77

References to Aleutian Island Wetlands 79

Pond and lake 80

Fresh water marsh 81

Peatland 83

Stream 85

Riparian gravel bar and cutbank 86

Strand and supratidal meadow 87

Intertidal zone 89

Succession in general 90

Vegetation maps 90

BERING SEA ISLANDS 93

References to Wetlands of Bering Sea Islands 94

Pond and lake 95

Fresh water marsh 96

Peatland 96

Riparian gravel bar and cutbank 98

Strand and supratidal meadow 99

Saline or brackish marsh 102

Intertidal zone 102

Vegetation maps 102

BERING SEA MAINLAND 103

References to Wetlands of the Bering Sea Mainland 106

Pond and lake 107

Fresh water marsh 108
Peatland 109
Riparian gravel bar and cutbank 111
Strand and supratidal meadow 112
Saline or brackish marsh 113
Intertidal zone 114
Vegetation maps 115
CHUKCHI SEA 116
References to Chukchi Sea Wetlands 118
Pond and lake 120
Fresh water marsh 122
Peatland 125
Stream 128
Riparian gravel bar and cutbank 129
Strand and supratidal meadow 133
Saline or brackish marsh 135
Intertidal zone 138
Vegetation maps 138
BEAUFORT SEA 143
References to Beaufort Sea Wetlands 146
Pond and lake 148
Fresh water marsh 153
Peatland 157
Stream 167
Riparian gravel bar and cutbank 168

Strand and supratidal meadow 173

Saline or brackish marsh 177

Vegetation maps 177

INTERIOR ALASKA 181

References to Interior Alaskan Wetlands 183

Pond and lake 185

Fresh water marsh 187

Peatland 191

Riparian gravel bar and cutbank 209

Vegetation maps 211

REFERENCES 214

LIST OF FIGURES

Figure		Page
1.	Geographic regions of Alaska.	5
2.	Wetland categories in relation to water regime and soil texture.	20
3.	Average percent cover for four species, relative elevation, and vegetation height for three major plant communities in the Kadashan tide-influenced meadow.	51
4.	Apparent lowland successional tendencies at Dixon Harbor, Glacier Bay National Monument.	53
5.	Cross-sectional diagram of the Copper River delta.	69
6.	Cross-sectional diagram showing zones of plant communities adjacent to a channel on the Copper River delta.	71
7.	Thre^ types of ponds on the Copper River delta with progressively greater accumulations of peat.	73
8.	A modal soil-depth profile through an upland tundra-lowland tundra transitional basin on Amchitka Island.	91
9.	Diagram representing the topographic relations of the chief habitats on the two main types of island in the Aleutian chain.	92

10. Generalized picture of the vegetation encountered in a transect from outliers of the Igichuk Hills to the mudflats of the Noatak delta. 139

11. Generalized picture of the vegetation encountered in a transect across the Mission Lowland in the Noatak River valley. 140

12. Generalized picture of the vegetation encountered in a transect from the Delong Mountains in the vicinity of Feniak Lake across the northern portion of the Aniuk Lowland to the main channel of the Noatak River. 141

13. Generalized picture of the vegetation encountered in a transect across the Noatak River valley near the headwaters. 142

14. Diagram showing the major landscape units of the upper Firth River valley. 179

15. Cross-sectional diagram of the valley of the Colville River and adjacent uplands in the vicinity of Umiat, Alaska. 180

16. Diagram of a transect through zones of riparian succession along a slough near Circle City. 186

17. Diagram of a transect through zones of shoreline vegetation on an oxbow lake near Circle City. 186

18. Idealized cross section of the upper Kuskokwim River floodplain. 194

19. Flow diagram of vegetation and physiographic processes on the upper Kuskokwim River floodplain. 196

20. Vegetation associations on the upper Kuskokwim River floodplain. 198

21. Distribution of bog species along a moisture gradient. 203

22. Diagram of vegetation types along a topographic gradientin Interior Alaska. 204

23. Diagrammatic cross section of typical distribution of vegetation and permafrost across a meander of a river in Interior Alaska. 212

24. Diagrammatic profile of the Iliamna Lake area showing topography and ecologic formations. 213

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
fathoms	1.8288	metres
feet	0.3048	metres
inches	25.4	millimetres
miles per hour (U.S. statute)	1.609344	kilometres per hour
miles (U.S. statute)	1.609344	kilometres
tons (2000 lb, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use $K = (5/9)(F - 32) + 273.15$.

A LITERATURE SURVEY ON THE WETLAND VEGETATION OF ALASKA

INTRODUCTION

This report contains a relatively comprehensive summary, through July 1977, of the literature pertaining to the wetland vegetation of Alaska. The literature was found to be scattered; however, most of the relevant botanical papers have been incorporated. This summary does not include an analysis of the literature on waterfowl biology and management, nor is any information from the ongoing Outer Continental Shelf Environmental Assessment Program studies included. Both sources will yield additional data, although they may not substantially alter the literature summaries provided.

Even after an exhaustive review of wetlands literature, it will be clear that there are large gaps in our knowledge of wetland ecosystems. Specific wetland descriptions from relatively few localities form the basis for our knowledge. Consequently, we must guard against unwarranted extrapolations beyond the data when attempting to predict conditions distant from these known sites.

Alaska is such a large state that one intuitively knows that any attempt to develop a single treatment of so widespread a landscape unit as wetlands demands rather careful internal organization. Few statements can be made that will apply equally well to all wetlands, and these would be so necessarily general as to have limited biological relevance.

Alaska ranges in latitude from 51°16'N on Amatignak Island in the

Aleutians to 71°23'N at Point Barrow, and in longitude from 130°00'W at Camp Point to 172°28'E on Attu Island (Orth, 1967). Vast lowlands and rugged mountains are abundantly represented in Alaska as well as topography intermediate between these two extremes. Temperature extremes range from +100° F to -80° F.* Average annual temperatures vary from 45° F in the Ketchikan area to less than 10° F at Barrow; average yearly precipitation varies from more than 320 inches on parts of Baranof Island to less than 10 inches in the Arctic Coastal Plain (Viereck and Little, 1975). Stretching as it does over 20° of latitude and with the tremendous variety of climatic conditions, it is not surprising that Alaska has a diverse array of wetlands. Nor is it surprising that superficially similar wetlands in different parts of the state will react differently to any changes in the geomorphological or biological factors with which each wetland is in balance.

The coastline from Ketchikan to Barrow traverses three major biotic zones: Pacific Coastal, Subarctic, and Arctic. There are remarkable differences in the amplitude of tides, discontinuities in bedrock geology, and vastly different shoreline conditions determined by glacial activity, historical and present. Over the full latitudinal extent, variations of solar radiation--angle of incidence, intensity, diurnal and seasonal duration--present an enormous cline with markedly distinct extremes. Summer temperatures and total accumulated warmth (degree days) during the growing season vary along the cline as does the amount and form of precipitation. The seasonal occurrence of sea ice is another variable

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page x.

that influences nearshore terrestrial habitats. Thus the changes in values with latitude for a number of environmental parameters determine an array of sites, each with slightly different features to which the biota must adapt. The widespread plants attest to successful adaptation, presumably through adjustments of genetic-biochemical-anatomical reactions Therefore the same species at different localities is the same only in the context of its taxonomy. Other taxa that do not exhibit broad ecological tolerances or a continuum of ecotypes are limited in their distribution and help define the major zonation.

The fresh water wetland systems are similarly affected by physiography and history of the landscape; latitudinally determined aspects of the physical environment produce different adaptive norms and different ecosystems. All fresh water wetlands will freeze during the winter, but some are frozen for as long as nine and ten months in arctic Alaska.

Within any one region, large meandering rivers actively erode steep cutbanks and deposit point bars, constantly reworking the riparian zone. The vegetation is in a continual state of destruction and renewal. Periodic flooding, either at spring breakup or during late summer warm spells (for rivers with headwaters in glacierized mountains), produces overbank deposits of silts and sands but also accounts for occasional catastrophic changes in the landscape. Channel changes produce quiet sloughs and oxbow lakes, both important fresh water wetland types.

WETLAND REGIONS

For the purposes of this report, Alaska is divided into eight geographic regions in the hope that more valid generalizations can be made about wetland types within a specific region than can be made over the state as a whole. For example, a brackish marsh at Barrow has little similarity to a brackish marsh on Chichagof Island other than the salinity of its water supply and possibly the soil texture.

The eight regions (see figure 1): 1) Southeastern Alaska, all of Alaska east and south of Cape Fairweather including inland and mountainous areas. 2) Southcentral Alaska, the southern Alaskan coast from Cape Fairweather to Cape Providence on the south side of the Alaska Peninsula. This region also includes the Chugach Mountains, the Matanuska Valley, the Susitna delta, the southeast slope of the Aleutian Range, and all islands off this sector of coastline, including Kodiak Island. 3) Aleutian Islands, the Alaska Peninsula west of Cape Providence on the south and Cape Menshikof to the north. 4) Bering Sea Islands, St. Lawrence, St. Matthew, Nunivak, and the Pribilof Islands, 5) Bering Sea Mainland, the coast from Cape Menshikof to Cape Prince of Wales (including Nelson Island) and extending inland to the limit of more or less continuous spruce forest. 6) Chukchi Sea, the Chukchi Sea coast between Cape Prince of Wales and Icy Cape and the lands drained by rivers entering the Chukchi Sea between these points, including the Kobuk and Noatak Rivers. 7) Beaufort Sea Coast, the Beaufort Sea coast from the Canadian border to Point Barrow and that part of

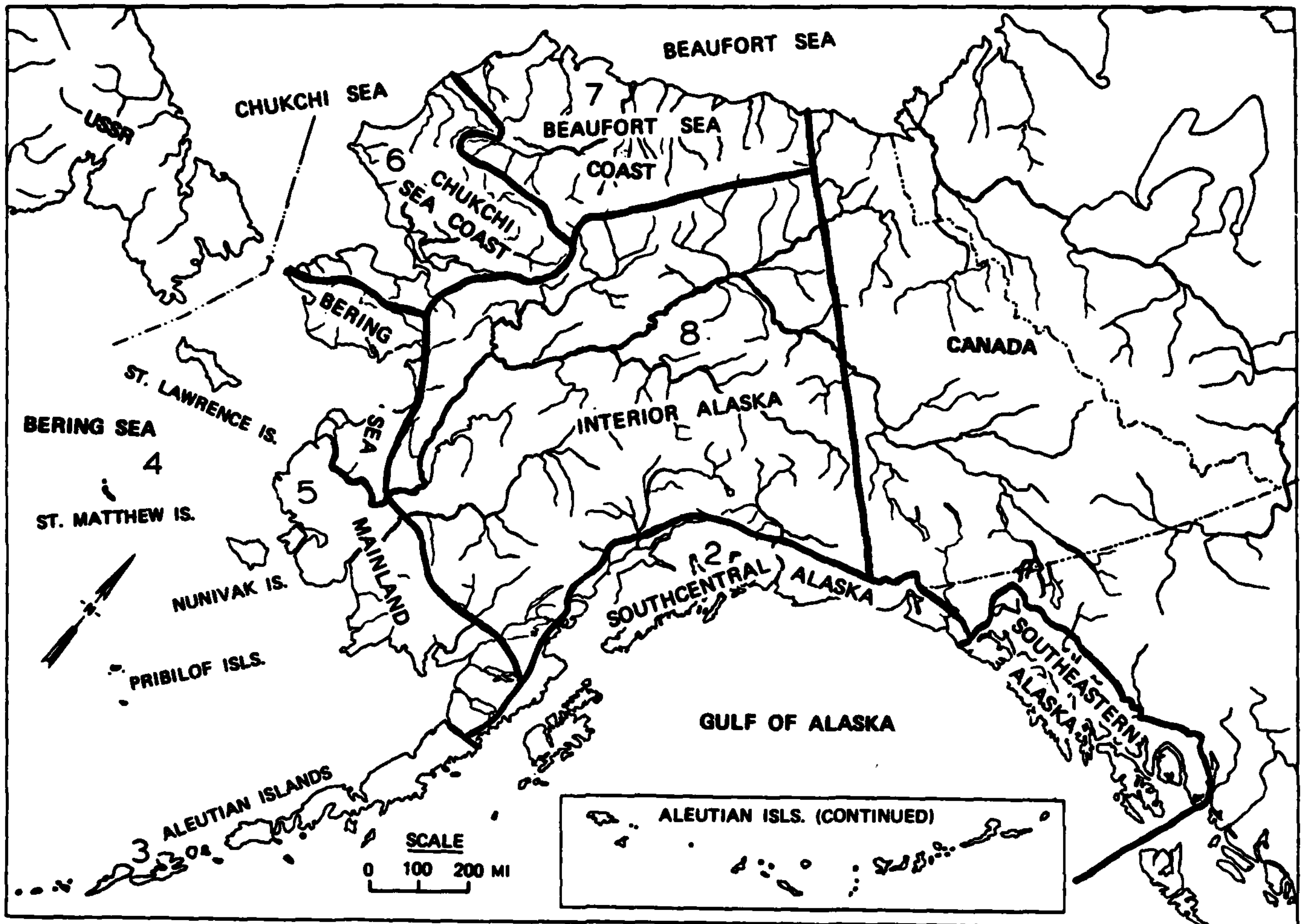


Figure 1. Geographic regions of Alaska. The numbers refer to the eight geographic regions described in the text.

the Chukchi Sea coast between Icy Cape and Point Barrow. It also includes all of the terrain drained by rivers that enter the Arctic Ocean between these points as well as the upper drainages of tributaries of the Yukon River as far south as the limit of more or less continuous spruce forest. The reason for including the northwestern part of the Chukchi Sea coast in the Beaufort Sea region is to make most of the Teshekpuk Lake section of the Arctic Coastal Plain (Wahrhaftig, 1965) fall within one region. 8) Interior Alaska, all of Alaska not included in any of the foregoing regions. It is essentially that part of Alaska inland from, and exclusive of, coastal ranges. It also corresponds in large part to that part of Alaska vegetated principally by black and/or white spruce forests, except that the Kobuk Valley and the upper Cook Inlet-Matanuska Valley areas, parts of which are so vegetated, are placed in other regions. On one hand, these regions are fairly discreet units wherein some of the major factors affecting the vegetation--such as climate, prevailing winds, and presence and duration of sea ice--are similar throughout each. On the other, exact boundaries are arbitrary and, in several cases, conveniently drawn through the middle of large gaps in our information. Even within regions, vegetation types are by no means constant; bogs at Katmai (Griggs, 1936) differ in several respects, both physiognomic and floristic, from bogs in the Prince William Sound area (Cooper, 1942).

An important criterion for differentiating fresh water wetlands from brackish water wetlands in this report has been vegetational. The occurrence of such plants as *Hippuris tetraphylla* in pond margins or *Carex subspathacea*, *C. glareosa*, or certain other species in marshes usually

indicates a certain amount of salinity or a consistent periodic exposure to salinity. In some instances, however, it is difficult to tell how far the saline influence extends. Some littoral zone biologists work within a range defined by mean high tide, but in some regions and for the study of certain organisms, the upper limit of storm tides as indicated by debris lines is more relevant.

WETLAND CATEGORIES

The format followed in this report groups Alaska's wetlands into eight very broad categories. The literature is reviewed for each of these categories within each of the eight geographic regions. These eight categories are not to be considered wetland types but are merely a broad framework in which to discuss specific vegetation types. They are:

Fresh water wetlands

1. Pond and lake
2. Fresh water marsh
3. Peatland
4. Stream
5. Riparian gravel bar and cutbank

Saline or brackish water wetlands

6. Strand and supratidal meadow
7. Saline or brackish marsh
8. Intertidal zone

1) Pond and lake. This category includes submersed, floating, and emergent aquatic vegetation, as well as ponds and lakes that are unvegetated. Ponds and lakes can be fresh or slightly brackish, but in general only fresh water lakes are included here; brackish ponds are described in the saline or brackish marsh category. Often several vegetation zones controlled by water depth are evident in ponds; therefore two broad subunits can be differentiated in many lakes: a) submersed and floating aquatic plants in relatively deep water, and b) emergent aquatics

in shallower water. The vegetation of pond margins can intergrade with that of surrounding fresh water marsh or peatland and with the stream category in the case of sluggish sloughs in the process of becoming oxbow lakes or oxbow lakes that temporarily contain flowing water during high runoff periods. Very small ponds are generally not considered here but are included in the description of the vegetation type surrounding them, usually fresh water marsh, saline or brackish marsh, or peatland.

Ponds and lakes originate in several different ways. Kettle lakes occupy basins in moraines and ice-contact stratified drift and are caused by the melting of blocks of ice subsequent to glacier retreat. Some kettle lakes are very young and are still unvegetated. Oxbow lakes result from river-deposited sediments blocking off the upper and lower ends of sloughs. These are common on floodplains in all parts of Alaska. Small "pit" ponds and even larger ponds are found on bogs and apparently result from processes inherent in the bogs. Large, deep lakes result from the damming of ice-scoured mountain valleys by glacial moraines. Several of these lakes are found in the Brooks Range, the Aleutian Range, and the mountains northwest of Dillingham. Occasionally impoundments are the result of the damming of rivers by glaciers. In the interior of Alaska, several large but shallow lakes have developed when actively aggrading, glacier-headed rivers have deposited dams of alluvium at the mouths of unglaciated tributaries. On the Seward Peninsula there are lakes occupying bedrock basins. Thaw lakes develop when disturbance of the insulating vegetation cover exposes ice-rich permafrost to melting. Subsidence produces water-filled depressions.

These are common throughout the northern two-thirds of the state on lowlands underlain by permafrost.

All of these lakes and ponds are in the process of being filled in, either by deposition of mineral material carried by rivers or winds or by accumulation of vegetable matter. However, the rate of filling varies drastically between different kinds of lakes and different regions of the state. Oxbow lakes, bog ponds, and thaw lakes are continually developing at the present time, renewing the supply of lakes as the old ones fill in.

2) Fresh water marsh. This category includes all wetlands occurring on mineral soils (or on less than 30 cm of peat) or on shallow mucks (less than a meter thick). Included are sites that are permanently flooded with shallow water, intermittently flooded, and sites seldom or never flooded but very wet throughout all or most of the year.

The fresh water marsh category represents areas dominated by graminoid vegetation as opposed to the vegetation consisting predominantly of woody plants and herbs and more characteristic of riparian gravel bars and cutbanks. Emergent vegetation along river margins is included, however. This category frequently intergrades with peatland, pond and lake, stream, and saline or brackish marsh, sometimes also with the strand and supratidal meadow, and riparian gravel bar and cutbank categories. In particular, fresh water marsh can often be only arbitrarily separated from peatland; for further discussion see the peatland section.

Vegetation discussed under the fresh water marsh category generally falls into three main types. Typical marsh is usually found around the margins of kettle lakes and ponds on moraines and outwash in recently deglaciated regions, on wet or flooded silt bars on floodplains and deltas, along the margins of rivers, and on gently sloping benches receiving water from steeper slopes above. This kind of marsh is found throughout Alaska though its abundance depends on the abundance of floodplains and deltas and the rate of peat accumulation on wet habitats. Alpine and subalpine wet meadows of marsh-like vegetation occur on wet mineral soils in alpine valleys, in swales on alpine and subalpine slopes, around springs and seeps, and below snowbeds in areas well irrigated by meltwater. These communities may have little floristic similarity to each other as they occur wherever there are mountains, and mountains are well represented in all eight regions of the state. However, these types of vegetation are rarely discussed in the literature. Eriophorum-tussock tundra can occupy wet mineral soils on vast areas of undulating uplands in the Beaufort Sea and Chukchi Sea regions.

In many areas of Alaska, where mineral soil is not being supplied by fluvial or other processes, and where the rate of production of vegetable matter exceeds the rate of decomposition, marshes begin to accumulate organic matter and eventually succeed to peatlands.

3) Peatland. This broad category includes a large and diverse array of vegetation units. The primary unifying characteristic is that

they are underlain by at least 30 cm (12 inches) of peat, or, as in the case of bogs on active flood plains [such as those on the upper Kuskokwim River (Drury, 1956)], by a meter or more of organic-rich muck. Bogs and wet tundra are the vegetation units most commonly recognized as peatlands, although some units commonly called marshes are also included. The peatland category intergrades with the fresh water marsh and the pond and lake categories and, rarely, with the saline or brackish marsh category.

There are many actual kinds of peatlands in Alaska, but the diversity of names which have been applied to them is perhaps even greater. Muskeg is a term that, in most instances, has been used synonymously with bog. Many authors distinguish sedge bogs and moss bogs while others reserve the term bog for moss bogs and refer to sedge bogs as fens. However, examination of peat cores has revealed that many bogs in Southeastern, Southcentral, and Interior Alaska have been both sedge-dominated and moss-dominated at different times during their development (Dachnowski-Stokes, 1941).

Three different kinds of bogs have been recognized based on the nature of their water supply, which in turn relates to their mineral and cation supply. Ombrogenous bogs (also called raised bogs or tertiary mires) have an upper surface that is dome-shaped or convex independently of the topography of the underlying mineral substrate. The water table is raised above that of the surrounding area, and moisture is supplied only by rainwater. These bogs have a very low pH, are poor in minerals and cations, and are generally dominated by mosses of

the genus Sphagnum. Soligenous bogs (also called slope bogs or secondary mires) are bogs on slopes, the bog surface more or less conforming to the topography of the underlying mineral substrate. Water enters the bog primarily as ground water and surface runoff from upslope and contains dissolved minerals and cations derived from mineral soil. The pH of these bogs is generally higher, and sedges are usually more important in the vegetation. Topogenous bogs (also called flat bogs or primary mires) occur in potholes on valley bottoms. The bog surface is controlled by the water table. These bogs also have a relatively high pH, and sedges are normally important in the vegetation. A specific bog can change from one kind to another and back again depending on climate and conditions controlling decomposition (humification) and water retention within the bog, somewhat irrespective of topography. Another term frequently used is blanket or oceanic bog,which refers to bogs that blanket large areas of rolling topography and usually contain both ombrogenous (raised) and soligenous (slope) elements. Topogenous and soligenous bogs are found throughout Alaska, but raised and blanket bogs are restricted to the Southeastern and Southcentral regions.

Most authors discussing the bogs of Southeastern, Southcentral, and Interior Alaska have recognized raised, slope, flat, and blanket bogs, but they often fail to make clear just which of these types they are dealing with when discussing specific bogs. Also, the concepts of slope, blanket, and raised bogs seem to differ somewhat between different authors, notably Dachnowski-Stokes (1941), Heusser (1960), and

Neiland (1971). Worley (1972) feels this bog classification system may not be the most meaningful way to interpret bogs and that it needs reevaluation.

The peatlands of Alaska can be roughly divided into four main kinds on the basis of distribution and physiognomy. This classification is more or less independent of the classification based on water supply. a) Bogs of filled-in lakes. These are mostly topogenous bogs as discussed above and are widespread throughout the state. b) Bogs of Southeastern and Southcentral Alaska. These bogs have no permafrost, are found primarily on interfluves, and are maintained by an abundance of precipitation. c) Bogs of Interior Alaska. The existence of these bogs is closely related to permafrost which when occurring at shallow depths inhibits drainage. The existence of the permafrost, in turn, is dependent on the insulating properties of the vegetative cover. There are bogs in interior Alaska where permafrost is lacking or deeper than 2-3 m; however, these bogs are dependent on the melting of ice-rich permafrost for their initiation and expansion. d) Wet tundra. Wet tundra is widespread on peaty soils with or without permafrost in northern and western Alaska; in alpine areas throughout the state; and, in the form of heath vegetation, on the Aleutian Islands.

Topogenous and soligenous bogs can develop from marshes as peat accumulates. This process is effective throughout Alaska. In Southeastern, Southcentral, and Interior Alaska, soligenous and raised bogs can develop through the swamping of forests caused by the increasing thickness of a water-saturated moss layer (paludification), by the melting of ice-rich permafrost, or by the rising of the permafrost table

in response to the development of a thick mat of insulating vegetation.

It is often difficult to differentiate peatlands from fresh water marshes. The requirement of more than 30 cm of peat to define peatlands is arbitrary but was adopted as a useful means of splitting the tremendous diversity of water-saturated and shallowly flooded fresh water wetlands into units. Thirty cm was chosen as the breaking point because it is the minimum amount of peat accumulation required for a soil to be classified as a half-bog soil in the soil classification system devised by Tedrow and his associates in the Alaskan Arctic (Tedrow, 1973). However, separating peatland vegetation from fresh water marsh vegetation, as described in the Alaskan literature, has been difficult, since information on substrate is often not given. In northern and western Alaska in particular, the vegetation seems to respond to differences in soil moisture more than it does to differences in the thickness of the organic mat. In addition, the development of peatlands is sometimes complicated by the mixing of large quantities of silt with the organic material by fluvial or aeolian processes to produce a muck (Drury, 1956). In this report, sites in which the muck is a meter or two or more deep and is highly organic are considered peatlands. Sites in which the muck is thinner and more mineral are considered fresh water marshes.

Another problem important in areas where permafrost lies close to the surface is that of scale. Where ice-wedge polygons have developed, wet boggy vegetation growing over the ice wedges [Porsild's (1939) "bog-filled frost cleavages"] may exist only a few feet, or even inches,

from more mesic vegetation of the tops and sides of high-center polygons. In these cases two (or sometimes more) vegetation elements form an endlessly repeating network across the landscape. A decision must be made to either recognize both elements types as separate, but intertwined, vegetation types or to recognize a single composite type.

4) Stream. This category includes floating and submersed vegetation growing in perennial streams but does not include emergent vegetation growing along the margins. In most instances streams are an unvegetated wetland. Marginal emergent vegetation is included in the fresh water marsh category, with which the stream category intergrades.

5) Riparian gravel bar and cutbank. This includes vegetation dominated by woody plants and perennial herbs growing on gravel and sand bars and cutbanks of rivers. These areas are subject to annual, or at least periodic, inundation during spring floods or summer precipitation and snowmelt peaks. During dry spells these sites may become quite xeric. This category sometimes intergrades with fresh water marsh.

Four general types of vegetation are included in this category: a) perennial herbs on coarse, unstable, frequently flooded alluvium; b) shrub-dominated vegetation with an understory of perennial herbs, on coarse but more stable, less frequently flooded alluvium; c) perennial herbs on relatively fine-textured substrates alongside small entrenched tundra streams; and d) shrub thickets in ravines and swales.

6) Strand and supratidal meadow. This category includes beach herbs and grasses growing from the upper intertidal zone to sites well out of reach of ordinary tides but probably subject to flooding or spray during storm tides. Vegetation within this category on the foreshore normally occurs on soils consisting of fine sand or coarser material. Farther back from the beach organic material has accumulated in the soil, resulting in a more loamy texture. These back-beach areas are very seldom or never flooded by fresh water but may be fairly moist. Vegetation of rocky shores and sea cliffs is also included in this category. The strand and supratidal meadow category intergrades with the saline or brackish marsh and the fresh water marsh categories.

Four main types of vegetation are included in this category: a) a zone of widely scattered halophytic herbs on the foreshore; b) a zone dominated by dense stands of *Elymus arenarius* with associated scattered halophytic herbs on dunes or beaches above ordinary high tides; c) a zone landward from the *Elymus* zone, where *Elymus* decreases in importance and a variety of herbs, grasses, and sedges gain in importance; and d) miscellaneous habitats such as coastal bluffs, sea cliffs, and rocky shores.

Factors controlling the distribution of plants on the strand include the salinity of these sites, the erosive effects of waves and winds, and the erosive effect of sea ice during breakup in northern and western Alaska. Sea ice is a very effective agent of erosion and is largely responsible for the paucity of vegetation on exposed beaches in northern and western Alaska (Hanson, 1951; Wiggins and Thomas, 1962).

7) Saline or brackish marsh. These sites are on or near low-energy, nearly level shores with fine-textured soils near the mouths of rivers. They are flooded with saline or brackish water often enough that plants characteristic of seacoasts and brackish water grow there. Small brackish water ponds are included in this category. The vegetation is dominated by graminoid plants. This category intergrades with the strand and supratidal meadow and the fresh water marsh categories and sometimes with the intertidal category.

Three general vegetation types are included in this category: a) sparse vegetation, usually dominated by species of *Puccinellia* with few associates on the most saline and frequently flooded sites; b) more dense and diverse vegetation dominated by sedges farther landward, but still usually affected by tides; and c) brackish ponds supporting a variety of species, usually including *Hippuris tetraphylla*.

It is difficult to differentiate precisely between slightly brackish marshes and fresh water marshes. *Carex lyngbyaei* is common in brackish water along the coast of Southcentral and Southeastern Alaska but apparently also grows in fresh water (Griggs, 1936). In some areas of Alaska, notably the Beaufort Sea coast, small amounts of salt have been carried far inland (to sites treated here as fresh water) by storm winds, fogs, and ice crystals.

8) Intertidal zone. Sites that, strictly speaking, would be considered shallow subtidal are included in this zone. It includes unvegetated mud flats and areas vegetated with macrophytic algae or,

in the southern two-thirds of the state, with Zostera marina. In general, Zostera grows in soft, muddy substrates in shallow, clear water in protected bays, inlets, and lagoons. Macrophytic marine algae are usually found along more exposed coasts on rocky substrates, sometimes growing in quite deep water.

The relationship between soil texture, water regime, and these broad wetland categories is illustrated in a simplified, generalized way in figure 2.

In the following pages each category of wetland vegetation is discussed for each geographic region of Alaska. Preceding the synopses for each is a list of references to wetlands for that region. An overview of the physiography, climate, and vegetation is presented first, followed by descriptions of specific vegetation units abstracted from the botanical literature. Introductory paragraphs not attribued to a source are our own. Unless information is bracketed [ ], all paragraphs (and page numbers) after a cited reference are abstracted from that reference. Bracketed material includes references to figures reproduced for this report. The abstracts proceed alphabetically within each of the broad wetland categories outlined above. In some instances where a particular vegetation unit is transitional between two of the eight wetland categories, an abstract is included in both. Species concepts of the original authors are maintained, and no attempt is made to correlate the species names used with those used by Hultén (1968, 1973).

Water Regime

Soil Texture		Periodically flooded	Shallow permanent	Deep permanent
	Sand and coarser	Riparian gravel bar & cutbank Strand & suptratidal meadow Intertidal zone	Pond & lake Stream	Pond & lake Stream
	Silt and finer	Fresh water marsh Saline or brackish marsh Intertidal zone	Pond & lake Stream Fresh water marsh Saline or brackish marsh	Pond & lake Stream
	Organic	Peatland	Pond & lake Stream	Pond & lake Stream

Figure 2. Wetland categories in relation to water regime and soil texture.

SOUTHEASTERN ALASKA

This is a land of rugged topography dissected by abundant fjords. Much of the land exists as islands, thus the sea is never very far from any part of the region. High mountains with extensive glaciers and ice-fields occupy much of the mainland, and some of the glaciers reach tidewater where they discharge icebergs into the fjords. Most of the islands are also mountainous, but the mountains are not as high and glaciers are lacking or very small. Permafrost is not present in this region (Wahrhaftig, 1965). Lowlands are small and widely scattered since the land surface in most areas descends abruptly from mountain slopes to the sea. A few major rivers with headwaters in Canada traverse the mainland part of this region, but most drainages are short and steep.

The climate is conspicuously maritime with cool summers, mild winters, and abundant precipitation in all seasons. The average annual temperature ranges from 45° F in the south to 35° F in the north. Average annual precipitation varies from 320 inches on part of Baranof Island to 40 inches on part of Admiralty Island, but most of the region receives 80 to 160 inches annually (Viereck and Little, 1975). The vegetation consists primarily of coastal spruce-hemlock forest (Viereck and Little, 1972), bogs, and alpine tundra. Below timberline the bog and bog-transitional vegetation occupies almost as much area as does the forest (Neiland, 1971). In general the forests occupy the steeper slopes and well-drained fringes near the ocean and along streams, whereas the

bogs occupy poorly drained gentle slopes and level benches. The fjords give the region many miles of coastline. Estuaries and saline marshes are not abundant but occur scattered throughout the region. Tidal fluctuations are relatively high in this part of Alaska; extreme high and low tides range from 12 to 21 ft above mean sea level and 3 to 4 ft below mean sea level (Johnson and Hartman, 1969).

References to Southeastern Alaskan Wetlands

Cooper, William S. 1931. A third expedition to Glacier Bay, Alaska. Ecology 12:61-95.

Cooper, William S. 1939. A fourth expedition to Glacier Bay, Alaska. Ecology 20:130-155.

Dachnowski-Stokes, A. P. 1941. Peat resources in Alaska, U.S. Dept. Agr. Tech. Bull. No. 769, 84 p.

Decker, Henry F. 1966. Plants, p. 73-79. In Goldthwait, R. P. and others, Soil development and ecological succession in a deglaciated area of Muir Inlet, Southeast Alaska. Inst. Polar Studies Report No. 20, Ohio State Univ.

Heusser, Calvin J. 1960. Late-Pleistocene environments of North Pacific North America. American Geographical Society Special Publication No. 35. 308 p.

Klein, David R. 1965. Ecology of deer range in Alaska. Ecol. Monogr. 35:259-284.

Lawrence, D. B. 1958. Glaciers and vegetation in southeastern Alaska. Am. Sci. 46:89-122.

McRoy, C. Peter. 1968. The distribution and biogeography of Zostera marina (eelgrass) in Alaska. Pacific Sci. 22:507-513.

Neiland, Bonita J. 1971. The forest-bog complex of southeastern Alaska. Vegetatio 22:1-64.

Palmer, L. J. 1942. Major vegetative types of southeastern Alaska. USDI Fish & Wildlife Service Report. Juneau, Alaska. 16 p.

Rigg, G. B. 1937. Some raised bogs of southeastern Alaska with notes on flat bogs and muskeg. Am. J. Bot. 24:194-198.

Shacklette, Hansford T. 1965a. A leafy liverwort hydrosere on Yakobi Island, Alaska. Ecology 24:377-378.

Shacklette, Hansford T. 1965b. Bryophytes associated with mineral deposits and solutions in Alaska. U.S. Geol. Surv. Bull. 1198-C, 17 p.

Stephens, F. R. and R. F. Billings. 1967. Plant communities of a tide-influenced meadow on Chichagof Island, Alaska. Northwest Sci. 41:178-183.

Stephens, F. R., C. R. Gass, and R. F. Billings. 1970. The muskegs of southeast Alaska and their diminished extent. Northwest Sci. 44:123-130.

Stevens, M. E. 1965. Relation of vegetation to some soils in southeastern Alaska, p. 167-180. In Youngberg, C. T., ed., Forest-Soil Relationships in North America. Oregon State Univ. Press, Corvallis.

Streveler, G. P., I. A. Worley, C. J. Terry, and R. J. Gordon. 1973. Dixon Harbor biological survey. Final report on the summer phase of 1973 research. U.S. National Park Service, Glacier Bay. 241 p.

Worley, I. A. 1972. The bryo-geography of southeastern Alaska. Ph.D. thesis, Univ. British Columbia, Vancouver. 715 p.

Pond and lake

Cooper, 1939

Pools on recently deglaciated terrain at Glacier Bay are colonized slowly by aquatic plants. Eventually they commonly support the following plants:

true aquatics

Potamogeton filiformis	Ruppia maritima

species of the marginal zone in shallow water and extending out over the gravels

Equisetum arvense	Juncus haenkei
E. variegatum	Philonotis fontana
Eriophorum scheuchzeri	Drepanocladus kneiffii
Carex vulgaris	D. revolvens

Eventually these ponds are taken over by mat-forming (peat-producing) sedges. Once these sedges (marsh phase) become firmly established the build-up of peat is rapid and these areas are rapidly transformed to young bogs which in turn are often colonized by tall shrubs.

Heusser, 1960

The centers of many pools on recently deglaciated terrain near the Mendenhall Glacier are occupied by Sparganium hyperboreum. Emergent plants growing about the margins include Hippuris vulgaris, Eleocharis palustris, and Equisetum variegatum. Eventually these areas will succeed to sedges (marshes) and later will be colonized by shrubs and eventually forest.

Palmer, 1942

Species found in ponds and lakes:

aquatics

Nymphaea polysepala	Myriophyllum sp.
Potamogeton spp.	

semi-aquatics

Menyanthes trifoliata	Scirpus spp.
Potentilla palustris	Juncus spp.
Hippuris vulgaris	Carex spp.
Naumbergia thyrsiflora	Ranunculus cymbalaria
Sparganium spp.	Eleocharis spp.
Triglochin palustris	Cicuta douglasii

Streveler et al., 1973

Species of sluggish sloughs and shallow ponds within the forest:

Eleocharis palustris	Menyanthes trifoliata
Sparganium hyperboreum	Equisetum spp.
Hippuris vulgaris	Fontinalis antipyretica (the only truly aquatic bryophyte)

ponds lack Eleocharis and Equisetum and uniquely contain Juncus oreganus ex cf. saxatilis, and Callitriche verna. Deeper waters of many forest bog ponds contain Nuphar polysepalum.

Lakes and ponds may remain as they are for a very long time or, cially the shallower ponds, may succeed to fresh water marshes.

Worley, 1972

The only mosses growing submerged in lakes and the deeper pools of slower-moving streams are Fontinalis antipyretica and other species of this genus. Thirty-four other species of bryophytes commonly growing on pool, pond, or lake margins are listed on page 55.

Fresh water marsh

Heusser, 1960

A hydrarch succession on recently deglaciated terrain near the Mendenhall Glacier begins with a floating vegetation stage and is subsequently replaced by an emergent aquatic stage (See lake and pond category). This in turn succeeds to tussocks of Carex hindsii, Calamagrostis canadensis, Eriophorum scheuchzeri, and E. russeolum with a varied assemblage consisting of Menyanthes trifoliata, Tofieldia occidentalis, Parnassia palustris, Platanthera dilatata, Mimulus guttatus, Pedicularis sudetica, and Polygonum bistorta. In time this vegetation is replaced by woody plants, including willow, blueberry (Vaccinium uliginosum), and Picea sitchensis,which will succeed to the spruce subclimax and ultimately to the climax Pacific Coastal Forest.

Klein, 1965

Alpine meadows on Woronofski Island support lush growths of sedges and grasses along with succulent herbs such as Fauria crista-galli and Caltha biflora.

Streveler et al., 1973

Marshes in the Dixon Harbor area of Glacier Bay are characteristically shallowly flooded. Certain localized areas within the marshes are high enough to emerge above the water level periodically, and are vegetated with Salix barclayi, Drosera rotundifolia, and Sphagnum spp. or may be more meadow-like with Salix barclayi, Fritillaria camschatcensis, Calamagrostis canadensis, and Carex spp. Most notable species of wet areas:

Carex lyngbyaei	Eleocharis palustris
C. saxatilis	Menyanthes trifoliata
C. cf. limosa-pluriflora	

In contrast to the above wet-dry mosaic, other marshes are more uniform and have as the prominent species:

Carex cf. aquatilis	Equisetum variegatum
C. lyngbyaei	E. palustre
Eleocharis palustris	

A narrow fringe of marsh-like vegetation occurs along stable, low-gradient streams. Equisetum variegatum, E. palustre, and a sedge (Carex lyngbyaei ?) extend from the floodplain into water several inches deep. Arctophila fulva occasionally forms dense stands in a narrow band from a few inches above to a few inches below average water level.

Fresh water marshes develop from lakes, ponds, sloughs, or rivers on recently deglaciated terrain, moraines, and outwash. Fresh water marshes persist as they are for some time, but many probably develop into bogs. Some marshes are invaded by shrubs and develop into deciduous shrublands, further succeeding to various forest types.

Worley, 1972

Marshes are infrequent but of diverse ecology. There has been no standardization of terminology (marshes, swales, swamps, mires), but they include "level treeless areas where the water table is frequently high or above the substrate surface." Twenty-three bryophyte species are characteristic of marshes; five are restricted to basic conditions. Forty species of bryophytes, listed on page 55, are found on sloping sites such as springs, rills, flushes, and seeps.

Peatland

Cooper, 1939

Considerable peat has accumulated under boggy vegetation on relatively young surfaces (less than 200 years). Several phases of bogs are found at Glacier Bay. The youngest is a quaking mat composed of sedges and grasses with open water in many places. Principal species are Carex limosa, C. spectabilis, Eriophorum chamissonis, and Calamagrostis scabra. Associated species include:

Sphagnum squarrosum	Hippuris vulgaris
Equisetum fluviatile	Nephrophyllidium crista-galli
Rumex occidentalis	Galium trifidum
Epilobium palustre	

Later a firmer mat forms in two phases:

1) wet phase, meadow-like

Equisetum fluviatile	Tofieldia intermedia
Rumex occidentalis	Habenaria viridiflora

Equisetum variegatum
Agrostis hiemalis
Calamagrostis scabra
Carex limosa
C. rostrata
Eriophorum chamissonis
Hippuris vulgaris
Habenaria dilatata
Spiranthes romanzoffiana
Polygonum viviparum
Parnassia palustris
Rubus stellatus
Epilobium adenocaulon
E. palustre
Menyanthes trifoliata

2) less wet phase, thicket-like with abundant willows, especially Salix commutata

Bryum pseudotriquetrum
Calliergon cordifolium
C. giganteum
Camptothecium nitens
Dicranum sp.
Hylocomium sp.
Marchantia polymorpha
Philonotis fontana
Tofieldia intermedia
Drosera rotundifolia
Empetrum nigrum
Pinguicula vulgaris
Equisetum variegatum
Carex aquatilis
C. brunnescens
C. leptalea
C. viridula
Juncus alpinus
J. arcticus
J. triglumis
Salix barclayi
S. reticulata
Vaccinium oxycoccus

These quaking sedge bogs build up a more compact layer of peat and become firmer wet sedge bogs which are invaded by willows, ericaceous shrubs, and mosses.

Dachnowski-Stokes, 1941

Dominants of slope muskegs are usually mixed communities of sedge and moss, and essentially the same vegetation grows on bogs on higher plateaus and mountain slopes as on those near sea level. Especially prominent are:

Scirpus caespitosus	Rhynchospora alba
Eriophorum angustifolium	Sphagnum spp.
E. vaginatum	

Raised bogs have an uneven surface with Empetrum nigrum, Vaccinium vitis-idaea, and Drosera on the hummocks and Rhynchospora and Eriophorum in the hollows. Ledum groenlandicum, Kalmia glauca, and Andromeda polifolia are dominant heaths. Small shallow pools of water are frequent but none represent former lakes or ponds.

Bogs are dominated by either sedges or Sphagnum, and this dominance is probably partially controlled by pH (affected by water supply, mineral concentration, etc.). Many of the peat profiles taken show sedge peat at the bottom and through much of the profile and often contain one or two layers of stumps of spruce or pine below the surface, presumably representing previously forested conditions during drier intervals.

Flat bogs on a gravel-floored valley of the Herbert River (near Juneau) support an abundance of Eriophorum spp. and Menyanthes trifoliata. Eriophorum is active in peat formation. The quaking sedge-mat stage persists longer than the thicket and conifer stages.

Heusser, 1960

Pinus contorta in Southeastern Alaska is almost entirely restricted to bogs. Slope bogs have a shrubby cover, usually consisting of:

Vaccinium uliginosum	Empetrum nigrum
Kalmia polifolia	Juniperus communis
Ledum palustre	

and typical herbs:

Carex pauciflora	Tofieldia occidentalis
Scirpus caespitosus	Coptis trifolia
Eriophorum angustifolium	Drosera rotundifolia
Rynchospora alba	Sanguisorba menziesii
Lycopodium annotinum	Cornus canadensis
	Rubus chamaemorus

and mosses mostly of Sphagnum spp.

The peat of raised bogs appears to be better aerated as evidenced by relatively better growth of pine and other trees. Sphagnum moss is the main peat contributor and often occurs over ligneous layers taken to indicate previously forested conditions. Species found are:

Vaccinium uliginosum	Eriophorum angustifolium
V. vitis-idaea	Coptis trifolia
Andromeda polifolia	Drosera rotundifolia
Kalmia polifolia	Rubus chamaemorus
Ledum palustre	Cornus canadensis
Empetrum nigrum	Geocaulon lividum
Oxycoccus microcarpus	Lysichitum americanum

Carex pauciflora	*Scirpus caespitosus*

Pit ponds frequently occur on both slope and raised bogs and vary from small openings devoid of plants on raised bogs to large areas on slope bogs sometimes containing *Nuphar polysepalum*, *Nymphaea tetragona*, and *Potamogeton alpinus*.

Blanket bogs consist of sedge peat, are quite open, and may occur on plateaus and high slopes near timberline.

Flat (topogenous) bogs occur in broad, glaciated river valleys or extensive, poorly drained lowlands associated with lakes such as occur in pitted outwash plains. The source of water is the water table, and the peat accumulates in depressions to this level, which more or less limits its development. In an early stage these bogs exhibit a quaking character about the open pools. The vegetation may have a meadow aspect and consist of *Sphagnum* spp. along with:

Menyanthes trifoliata	*Caltha palustris*
Eriophorum scheuchzeri	*Potentilla palustris*
Lysichitum americanum	*Oxycoccus microcarpus*
Iris setosa	*Drosera rotundifolia*
Platanthera dilatata	*Fritillaria camschatcensis*
Sanguisorba sitchensis	

In later stages as moss peat accumulates, heath (*Andromeda polifolia*, *Ledum groenlandicum* and *Vaccinium vitis idaea*), *Myrica gale*, and conifer scrub become more conspicuous.

Topogenous bogs develop through a succession from aquatic plants to transitional sedge-grass communities and, in turn, to *Sphagnum* mosses and

heaths with conifers.

Lawrence, 1958

Skunk cabbage (*Lysichiton americanum*) appears to cause pit ponds in bogs by the shading effect of large, persistent, blackened, dead leaves preventing the growth of mosses. [For another opinion see Neiland (1971).]

Neiland, 1971

Bogs are non-forested, but a few scattered stunted individuals of *Pinus contorta* and *Chamaecyparis nootkatensis* (this latter species is common only in the southern part of Southeast Alaska) are found in most bogs. Of lesser importance are *Tsuga heterophylla*, *T. mertensiana*, *Picea sitchensis*, and *Thuja plicata*.

The bog communities examined fall into three main sets. Set 1 bogs are basically soligenous, conforming to underlying topography. Most have few surface ponds but some of the deeper ones have numerous steep-sided pit-ponds. Shrub species are in low frequency compared to other sets, and *Empetrum* occurrence is particularly low. Surface *Sphagnum* is continuous but fairly soft and loose, forming no mounds. Normally there is no water on the surface but it can be squeezed out by slight pressure. Bogs with shallow peats have large amounts of wood in the profile and a high frequency of *Lysichiton*. Several authors have stated that this species persists in bogs for some time after the forest in which it originated has been swamped.

The set 2 bogs are raised and/or blanket bogs and have the highest

number of Tsuga individuals of any bog type. Tsuga mertensiana grows prostrate; T. heterophylla grows erect but very small. Neither are numerous and their growth is very slow. Pinus contorta also grows in these bogs, T. heterophylla often growing at the base of pines. The surface Sphagnum layer is deep and firm or springy. Ledum, Empetrum, and Kalmia are all of high frequency and vigor. Andromeda has a high frequency in about half of these bogs. The general aspect is given by erect and fairly common Pinus individuals, by relatively tall shrubs, by vigorous scattered sedges (especially Carex pluriflora), and especially by a strongly undulant reddish brown Sphagnum surface. Ponds are common in some, rare in others. Rubus chamaemorus, Vaccinium vitis-idaea, and Carex livida are frequent. These are probably ombrogenous bogs. Surfaces are active or have been active recently since they rarely have ponds, and few if any dead patches occur on the surfaces. These have an increased aeration and average dryness and, at the same time, better moisture retention during drought than the other 2 bog types.

Set 3 bogs are raised bogs or the most raised portions of blanket bogs. Pinus is fairly common but exhibits slower growth than those on set 2 bogs. Although not prostrate, they are strongly centered. Shrubs are frequent but smaller than those on set 2 bogs. Species with high frequency are Eriophorum angustifolium, Rhynchospora alba, Sphagnum tenellum, and Scheuchzeria. Rounded grey-brown patches of Rhacomitrium and clumps of various lichens are conspicuous. The surface is usually very wet and composed of either exposed humified and slick peat or thin mats of live Sphagnum tenellum and S. compactum. Mats of Gymnocolea

are frequent. Sinuous, interconnected shallow ponds occupy much of the surface. The water-logged, slick, upper peat layers show the poorest preservation.

In contrast, during infrequent dry periods these become the driest of the bog surfaces. The dry shallow pond floors become cracked in polygonal patterns. These (set 3) bogs seem to be ombrogenous bogs that have stagnated in upward growth and have been subject to surface humification. These bogs seem particularly inhospitable to vascular plants since the peats near the surface are almost continuously water logged while at the same time the thin layer of surficial humified peat is subject to extreme desiccation during dry spells.

A review of primarily extra-Alaskan literature shows that in many places various environmental conditions are indicated by the plant species.

wet bog with permanently high water table

Drosera anglica	*Scheuchzeria palustris*
Lycopodium inundatum	*Sphagnum lindbergii*
Rhynchospora alba	

species conspicuous on dry-surfaced bogs

Rhacomitrium languginosum	*Sphagnum fuscum*
Trichophorum caespitosum	*Cladonia* spp.
Empetrum nigrum	other lichens

species indicative of higher nutrient levels

coarse sedges	*Selaginella* spp.

grasses | Sphagnum squarrosum

Carex pauciflora

species correlated with highest acidity

Pinus contorta | Sphagnum nemoreum

Sphagnum fuscum | Polytrichum strictum

S. compactum | Cladonia spp.

Sphagnum squarrosum does best at high, though subneutral, pH. Trees and shrubs generally require greater aeration for good growth than do most of the bog herbs and bryophytes.

Several small-scale patterns can be distinguished within southeastern Alaskan bogs. These are related to the relative dryness or wetness of the bog surface and the degree to which the surface is covered with apparently vigorous mosses. Wet surfaces include:

1) Pit-ponds. These have steep and often undercut banks and an apparent floor 15 to 45 cm below the general bog surface. This "floor" is usually a suspended mixture of highly decomposed peat and thick gelatinous masses of algae and fungi. Well-preserved and firm peat is found 15 cm to 1 m below the false floor. During extended dry periods these ponds dry up, but mats of Sphagnum form along the sides of the pit above the floor and retain water which can be squeezed out by slight pressure even after long dry spells.

2) Wet hollows. Shallowly concave areas are wet at all times but actually contain standing water only after periods of prolonged rain.

3) Surface drainage channels. Some bogs have none; in others they are conspicuous.

4) Mounds. Not very pronounced on these bogs. Set 2 bogs provide the widest array of dry subcommunities.

No unidirectional pattern of succession is evident. Bog forests and communities otherwise similar to upland forest, but underlain by deep moss-sedge peat deposits, occur thereby demonstrating that some bogs have been superceded by forest in relatively recent times. On the other hand some forests have been increasingly paludified, and other bogs and forests have remained stable for a very long time.

Preliminary working hypothesis: 1) some bogs are expanding into forests; 2) some soligenous bogs develop into ombrogenous bogs; 3) some soligenous bogs, possibly due to the slope and size of watersheds, remain soligenous; 4) some ombrogenous bogs are invaded by forest; 5) some ombrogenous bogs stagnate and are lowered in height by surface peat decay and erosion; and 6) any bogs with surfaces at all elevated above the plane of the underlying topography are extremely sensitive to fluctuations in rainfall and temperature.

In general, a continuous tension exists between 1) tendencies for better drainage, forest development, and raised bog humification and 2) poorer drainage, bog development, and raised bog growth. Developments improving drainage presumably include the raising, drying, and humification of bogs, development of drainage systems in bogs, and lowering of the water table and bog surface. Trends toward paludification presumably include restricted drainage due to growth of Sphagnum and other mosses. The vegetation at any given time and place depends on the particular combination of climate and physical surface features and the time lag

of vegetational and substrate response to climatic fluctuation.

Lysichiton americanum does not seem to affect the development of pit ponds, though it is often found growing on their edges. In some instances mosses are even closing off pit ponds and burying *Lysichiton*. [For another opinion see Lawrence (1958).]

Shacklette, 1965a

The following bryophytes are adapted to very wet sites on Yakobi Island and often grow in large patches on moderate slopes:

Paraleucobryum enerve	*Sphagnum papillosum*
Philonotis americana	*S. balticum*
Sphagnum compactum	

Communities of *Cassiope stelleriana* and *Fauria crista-galli* grow on mats of leafy liverworts built up over steeply flowing rivulets. These communities are thought to succeed to thickets of *Cladothamnus pyrolaeflorus*.

Stephens *et al.*, 1970

Three bog soil types are recognized for Southeastern Alaska. The Kogish series occurs in depressions on broad flats and consists of poorly decomposed moss peat from 8 to 40 ft thick with a surface layer of *Sphagnum* 4 to 12 inches thick. The vegetation is dominated by *Sphagnum*, but scattered stunted *Pinus contorta* and *Tsuga mertensiana* are found. *Picea sitchensis* and *Tsuga heterophylla* are rare. Common plants are:

Kalmia polifolia	*Oxycoccus microcarpus*

Andromeda polifolia — *Eriophorum* spp.

Ledum groenlandicum — *Empetrum nigrum*

Vaccinium vitis-idaea — *Dodecatheon* spp.

Juniperus communis — *Viola adunca*

Drosera rotundifolia

Kina soils are moderately decomposed sedge peats, 3 to 5 or
e feet thick, occurring on rolling benches, sloping hillsides, and
ad rolling ridgetops. The dominant vegetation is sedge with a com-
ent of grass and *Sphagnum* that may support a scattering of *Pinus*,
maecyparis, *Tsuga mertensiana*, and *Picea sitchensis*. Common plants
:

Menyanthes trifoliata — *Dodecatheon* spp.

Empetrum nigrum — *Eriophorum* spp.

Ledum groenlandicum — *Viola adunca*

Staney soils are poorly decomposed sedge peats occurring along the
gins of drainageways, lakes, and on broad flats as well as occupying
led and actively filling lakes. The water table is at or above the
face the year around. Dominant vegetation is sedges but with scattered
bs:

Sanguisorba menziesii — *Aconitum* spp.

S. sitchensis — *Limnorchis dilitata*

re are no living trees and little *Sphagnum*.

Stevens, 1963

Three bog soils are recognized for Prince of Wales Island. Maybeso

series, often supporting commercial forests; Kina series, in bogs with scattered scrubby trees; Peratovich series, on very poorly drained surfaces with little tree growth. Vegetation is principally moss-sedge with many transitions. Pure moss, pure sedge, moss and sedge, and ericaceous shrub communities may occur on the same bog.

Streveler *et al.*, 1973

At Dixon Harbor *Pinus contorta*, *Tsuga mertensiana*, and *Picea sitchensis* are most common on peat underlain by bedrock. Pine is generally absent; *Chamaecyparis nootkatensis* is occasionally present; spruce is more important on peats over outwash.

Soils are peat several centimeters to several meters thick; most are moist to wet, though periods of surface desiccation do occur. These soils are most common on level or gently sloping surfaces, but can occupy slopes up to 20°. Bogs are either *Sphagnum* dominated or *Carex* and *Trichophorum* dominated. These two interdigitate and replace each other. Several species of *Sphagnum* are capable of rapid expansion across sedgy areas, but these may eventually senesce and be replaced by sedges. Certain plants are common on almost all bogs, though they wax and wane with the dominance of major peat formers:

- *Trichophorum caespitosum*
- *Carex pauciflora*
- *Coptis trifolia*
- *Drosera rotundifolia*
- *Geum calthifolium*
- *Empetrum nigrum*
- *Vaccinium uliginosum*
- *V. oxycoccus*
- *Fauria crista-galli*

Mosses and liverworts, unlike the vascular flora, are highly sensitive to subtle differences in substrate, climate, and local geography.

Bogs may develop from fresh water marshes or from swamping of hemlock-spruce (cedar) forests or cedar-hemlock (pine) subforests and shrublands. "That outwash marshes can transform directly to peatlands is strikingly evident . . . ."

Worley, 1972

Open peatlands (muskegs) cover large tracts throughout nearly all of Southeastern Alaska. They form in depressions and on slopes from sea level to subalpine elevations wherever subsurface drainage is poor. Common species on these sites include mosses (mostly *Sphagnum* spp.), liverworts, sedges, and heaths (especially *Vaccinium* spp., *Kalmia polifolia*, *Ledum groenlandicum*, and *Empetrum nigrum*), and occasionally *Juniperus communis*. Shrubby or stunted trees are scattered over the bog surface. These are usually *Pinus contorta* and *Chamaecyparis nootkatensis* and sporadically *Tsuga mertensiana*, *Picea sitchensis*, and *Thuja plicata*. Under certain poorly understood conditions the peatland surface may develop an intricate assemblage of ponds that show slope-controlled orientation or patterning. Sixty species of bryophytes are common on these peatlands.

Stream

Shacklette, 1965a

Small cold streams on Yakobi Island, derived from melting snow flowing down steep ravines, are colonized by two species of leafy liverworts, Nardia compressa and Scapania paludosa. These plants are hydrophytic or submersed aquatic in habit and form dense tufts of intertwined stems. They are able to impound rivulets in a series of terraced pools. Water does not flow over the dams but filters through them, and eventually portions of the stream are forced to flow under the mats which are then colonized first by Cassiope stellariana followed by Fauria crista-galli. Eventually Cladothamnus pyrolaeflorus extends into the area forming inpenetrable thickets. By this time the rivulet has disappeared into the organic substrate and emerges as a stream farther down slope.

Streveler et al., 1973

Perennial swift water channels in the Dixon Harbor area of Glacier Bay seem devoid of vascular plant life. Stable, low-gradient sections of streams are occupied by a river marsh vegetation. Ranunculus trichophyllus is found to occupy moderate-velocity, fresh water streams. River channels can become sluggish sloughs which are eventually cut off to form oxbow lakes. These lakes slowly fill to form marshes which may be either colonized by shrubs and forest or may accumulate peat and become bogs.

Worley, 1972

Fontinalis antipyretica and other species of this genus grow submerged in lakes and in the deeper pools of slow-moving streams. Fourteen bryophyte species characteristic of emergent rocks of streams and rivers are listed in addition to 48 species commonly found on streambanks.

Riparian gravel bar and cutbank

Streveler et al., 1973

Shrublands dominated by alder or willow, or both, are extensive on the floodplains of glacial rivers. Areas flooded several times a decade have a depauperate understory often dominated by Equisetum spp. and two species of Pyrola. Areas flooded less frequently develop a variety of understories, varying from a marshy type, in which Equisetum spp. are joined by grasses and sedges, to a more mesic assemblage including a number of forest species.

Strand and supratidal meadow

A number of diverse vegetation units are included in this category. The most conspicuous and consistently recognizable one is a zone dominated by Elymus arenarius. The Elymus is usually thickest on sandy substrates out of reach of normal spring tides, but probably flooded by extreme storm tides. Toward the ocean Elymus decreases in density and is gradually replaced by scattered patches of halophytic herbs or by stands

of grasses such as *Puccinellia* or *Vahlodea*. Away from the ocean an increasing number of species are associated with the *Elymus*. Over most of the coastline there is a fringe of alder and willow with associated species that occurs between the supratidal meadows and the Pacific coastal forest. Other vegetation units included in the strand and supratidal meadow category are rocky shores and sea cliffs.

Cooper, 1931

Species of the beach meadow on a foreland at Glacier Bay are:

Agropyron violaceum	*Angelica genuflexa*
Elymus arenarius	*Dodecatheon pauciflorum*
Torresia odorata	*Gentiana acuta*
Spiranthes romanzoffiana	*Rhinanthus crista-galli*
Fragaria chiloensis	*Achillea borealis*
Lathyrus maritimus	*Senecio pauciflorus*

Decker, 1966

Beach meadows were formerly tidal areas but have been exposed by land rise (isostatic uplift following deglaciation). Soils are fertile, moist, and relatively fine-textured. Common species include:

Fragaria chiloensis (the most conspicuous plant)	*Botrychium lunaria*
	Campanula rotundifolia
Poa alpina	*Astragalus alpinus*
Calamagrostis canadensis	*Hierochloe odorata*

Klein, 1965

Common species of beach vegetation on Coronation and Woronkofski Islands are Elymus arenarius, Heracleum lanatum, Osmorhiza purpurea, and Conioselinum benthami. These areas receive heavy use by deer in the spring since vegetative growth begins here two weeks earlier than other sites.

Palmer, 1942

The most conspicuous plant of the beaches is Elymus mollis. Other grasses that often occur are Calamagrostis langsdorffii, C. aleutica, Hordeum nodosum, Agrostis spp., and cf. Glyceria. In addition, 44 other species are listed as characteristic of beaches.

Shacklette, 1965b

Bryophyte species known to grow in sea water are:

Scapania undulata	Eurhynchium praelongum
Arctoa fulvella	Grimmia maritima
Bryum inclinatum	Pohlia nutans

Twenty-three bryophyte species are found in the spray zone but above the high tide limit in Alaska.

Stephens and Billings, 1967

Ground well above ordinary high tides and at the edges of a tide-influenced meadow on Chichagof Island is dominated by Elymus mollis. Associated species include Deschampsia spp., Achillea spp., Potentilla

anserina, and Dodecatheon sp. The soil of this community consists of sands and gravels which have a higher pH and a lower cation exchange capacity and exchangeable cations than the frequently flooded adjacent lowlands.

Stevens, 1965

Delta land results from continued deposition in tidal areas, and is built up higher than adjacent tidal flats. The soils have a sporadic dark red iron pan 1/8 to 1/2 inch thick at the level of the mean high water table. Vegetation is chiefly thick stands of *Calamagrostis* sp., *Glyceria* sp., and *Elymus mollis* with *Achillea borealis*, *Castilleja* spp., and *Dodecatheon viviparum*. Sitka spruce invades these areas on higher better drained soils.

Streveler *et al*., 1973

Rocky shores are usually without vascular plants below the high tide limit, but rocky shores of quiet water areas near mean high tide often support *Puccinellia* spp., *Deschampsia* cf. *caespitosa*, *Plantago maritima*, *Cochlearia officinalis*, and *Grimmia maritima*.

Sheltered shorelines between rocky headlands have beaches of fine unconsolidated material varying in particle size from silt to gravel. Gravel beaches are sparsely occupied by *Honckenya peploides* and *Mertensia maritima*, which extend closest to the ocean of any vascular plants. *Elymus* forms swards in a belt just below the high tide limit.

On rocky shores above the high tide limit on exposed headlands

grow Deschampsia cf. caespitosa, Elymus arenarius, Festuca rubra, and Potentilla villosa. Near the upper edge of the splash zone, these species become more abundant and are joined by Ligusticum scoticum and Grimmia maritima. On rocky shores in quiet-water protected areas, above or slightly below the extreme high tide line, grow Elymus, Honckenya peploides, Brachythecium albicans, Rhytidiadelphus squarrosus, and Bryum spp. In cracks and rock faces along these quiet shores, where they are protected from persistent salt spray, grow the mosses Brachythecium, Rhytidiadelphus, Antitrichia curtipendula, Bryum spp., and Grimmia.

Lush herbaceous meadows exist on unconsolidated substrates above the high tide limit in many places in the Dixon Harbor area. These supratidal meadows have an aspect of a tall grassland above which project the fruiting heads of several herbs, particularly umbels. Elymus arenarius, Calamagrostis canadensis, and Heracleum lanatum are the usual dominants. A wide variety of forbs may be found, consistently including Lathyrus maritimus and Achillea borealis and often including Rubus spectabilis, Salix sitchensis, Alnus crispa, and Rhytidiadelphus loreus.

Certain unconsolidated marine beaches have been rising via deposition and uplift for the past two centuries. In these instances supratidal meadows replace the sparse vegetation of storm beaches and the upper intertidal zone. These meadows may themselves be replaced by spruce forests or by shrub thickets, either of which may succeed to various forest or bog types.

Worley, 1972

No bryophytes grow in habitats submerged by tidal waters. However, Grimmia maritima is common in rock crevices and other surfaces in the spray zone. In addition, five species are found on exposed rocks and larger crevices of headlands and sea cliffs, and 16 species are found on cliffs, boulders, among gravels, or on rocks of beaches and shores (listed on pages 50-52).

Fifteen bryophyte species grow in supratidal meadows (raised beaches--pre-shrub and/or pre-tree stages--listed on p. 51), and ten species more grow on driftwood on beaches (listed on p. 51).

Saline or brackish marsn

Cooper, 1931

Puccinellia paupercula and Glaux maritima and probably also Triglochin maritima, Hordeum boreale, and Plantago maritima grow in areas occasionally submerged by tides.

Klein, 1965

Carex lyngbyaei dominates marsh and beach areas below the extreme high tide level. It is associated with such halophytes as Atriplex gmelini, Honckenya peploides, and Triglochin maritimum. The Carex lyngbyaei is closely cropped by deer in the spring since vegetative growth begins earlier on the coastal fringe than on any inland sites.

Stephens and Billings, 1967

A pattern of three major plant communities is found in tide-influenced meadows near the mouth of a river on Chicagof Island. Lowest and nearest the ocean is the Carex lyngbyaei community, in which Potentilla anserina and Deschampsia spp. are also important. This community is frequently flooded with brackish water. The soil consists of 4 inches of peat overlying sands and gravels. On gentle slopes above this community and apparently above normal high tides occurs the Deschampsia atropurpurea community, in which Potentilla anserina, Elymus mollis, and Achillea spp. are also important. This community is the most variable of the three described in terms of species composition. [The third community, dominated by Elymus mollis, occurs on gravelly sands above the other two communities and is treated in the strand and supratidal meadow category of this report (see *figure* 3).]

Streveler et al., 1973

Silt or clay typically lines the lower portion of the most sheltered beaches, but often gravel occupies the uppermost intertidal zone. Upper intertidal silts and clays are most often found along river estuaries where freshwater influence allows a mixed intertidal-supratidal flora to occur. Commonly this flora is dominated by Carex lyngbyaei. Somewhat below this upper level is often a zone of Puccinellia nutkaensis and, at times, Deschampsia cf. caespitosa. Plantago maritima is also a typical member of this zone.

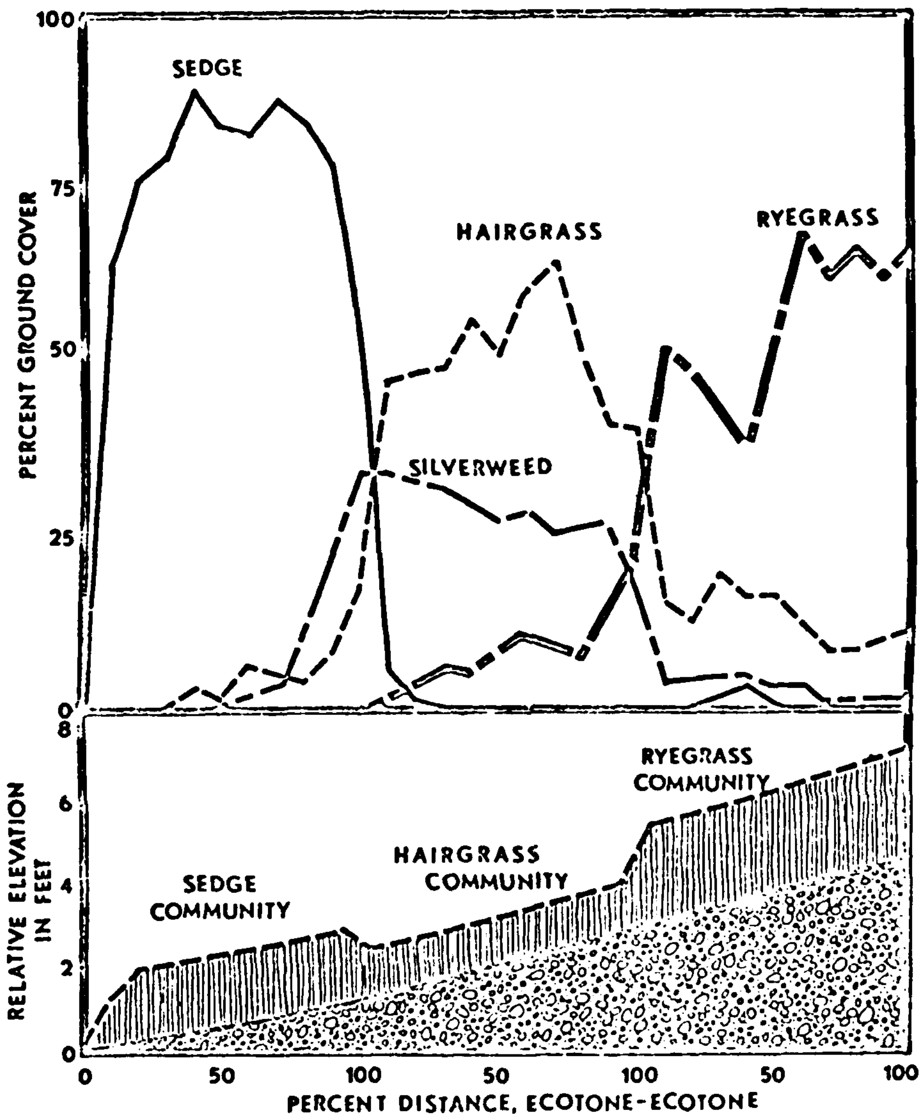


Figure 3. Average percent cover for four species, relative elevation, and vegetation height for three major plant communities in the Kadashan tide-influenced meadow. All percentages and elevations are averages determined in eight transects. (From Stephens and Billings, 1967, figure 3, p. 182.)

Worley, 1972

Few bryophytes are found in tide-influenced meadows--only *Eurhynchium praelongum* and *Brachythecium albicans* are common.

Intertidal zone

McRoy, 1968

Zostera marina is found in soft substrates in most of the bays and inlets of the outer coast of Southeastern Alaska but is absent from many of these on the inside waters, apparently due to the turbid effluent of glaciers.

Stephens and Billings, 1967

An unvegetated tidal flat occurs below and seaward of the *Carex lyngbyaei* community at the study site on Chichagof Island.

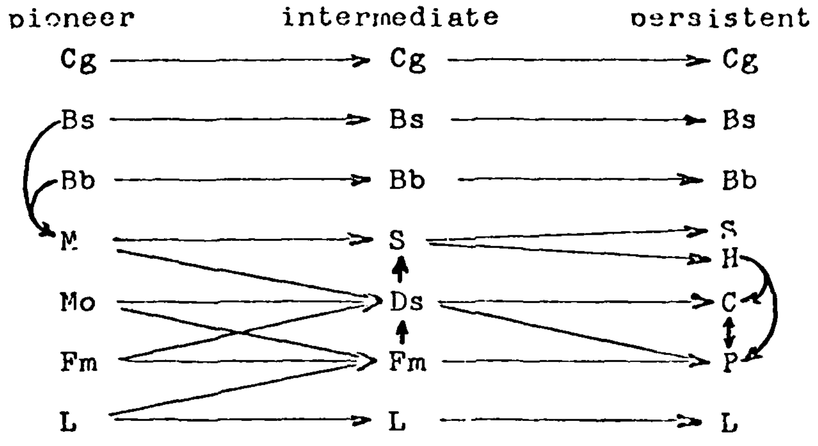
Stevens, 1965

On tidal flats of silty and clayey material deposited by rivers and reworked by tidal action grow species of *Fucus*, *Gigartina*, *Porphyra*, and *Ulva*.

Succession in general

Tentative successional tendencies for the Dixon Harbor area of Glacier Bay National Monument as worked out by Streveler *et al*. (1973) are shown here in figure 4.

Apparent Lowland Successional Tendencies



Vegetational communities

Bb	Rocky shores
Bs	Beaches of marine silts, sands, and gravels
M	Supratidal meadows
Fm	Freshwater marshes
P	Peatlands
C	Cedar, Hemlock, (pine), subforests and shrublands
S	Spruce forests
H	Hemlock, spruce, (cedar), forests
Ds	Deciduous shrublands
Am	Alpine meadows
Af	Alpine fellfields (including stony tundra and heaths)
As	Alpine snowbed margins
Mo	Barren moraines and outwashes
Cg	Cliffs and gullies
L	Lake, pond, slough, and river waters

Figure 4. Apparent lowland successional tendencies at Dixon Harbor, Glacier Bay National Monument. (From Streveler et al., 1973, figure F-1, p. 59, and appendix I, p. 134.)

ɟetation maps

Two vegetation maps of the Dixon Harbor area of Glacier Bay National ɿument are provided as maps 1 and 2 (in pocket on back cover) of reveler et al. (1973); a vegetation map of the Glacier Bay area is ɹnd in Cooper (1939, p. 134, figure 2); a map of northern Mitkof Island ɔwing bogs and forests is found in Dachnowski-Stokes (1941, p. 17, ɟure 4).

SOUTHCENTRAL ALASKA

This region is in large part a rugged coastline below a rugged mountain range. Throughout most of its length the coast faces open ocean, although numerous islands are found in Prince William Sound. Two large islands, Kodiak and Afognak, are included in the western part of this region. Numerous fjords dissect much of the coastline, although fjords are infrequent in Cook Inlet and east of Cordova where extensive lowlands are found. Glacier-clad mountains rise a short distance from the coast, and several glaciers reach tidewater and discharge icebergs into the sea. Small localized lowlands occur scattered throughout the region. A few large rivers, most notably the Copper and the Susitna, have their mouths in this region and have produced large deltas. Permafrost occurs sporadically in parts of the Chugach Mountains (Wahrhaftig, 1965). This region is mostly free of sea ice (except for occasional icebergs), but the upper part of Cook Inlet freezes each winter (Johnson and Hartman, 1969). Extreme high and low tides range from approximately 10 to 15 ft above to 3 ft below mean sea level but reach up to 33.4 ft above and 6 ft below mean sea level in upper Cook Inlet.

The climate is maritime except for Cook Inlet and the Chugach Range which are classified maritime-transitional (Johnson and Hartman, 1969). The average annual temperature varies from 40° to 30° F. Summers are cool and winters are relatively mild, though the average January temperature reaches 10° F in upper Cook Inlet, 10° to 15° F

cooler than most of the rest of this region (Johnson and Hartman, 1969). Precipitation is relatively high but substantially less than for most of Southeastern Alaska. Annual precipitation varies from 240 inches in parts of Prince William Sound to 20 inches in the Matanuska Valley (Viereck and Little, 1975). Winds are common and regularly reach gale force (32-63 mph) along the coast from September until June and annually reach hurricane force of 75+ mph (Isleib and Kessel, 1973).

Great changes occur between the eastern and western edges of this region. The vegetation below timberline in the central and eastern part is predominantly coastal spruce-hemlock forest, although the forest is considerably less diverse in tree species than it is farther south. In addition, forests of white spruce, black spruce, and paper birch, characteristic of the Alaskan Interior, penetrate into this region on the western Kenai Peninsula and the area around upper Cook Inlet (Viereck and Little, 1972). The forest becomes increasingly discontinuous west of the Kenai Peninsula and breaks up into small isolated groves and individual trees west of northeastern Kodiak Island and the southwestern Cook Inlet area (Viereck and Little, 1975). Bogs, similar to those of Southeastern Alaska, are prominent features of the landscape. A heath type of vegetation, not present near sea level in Southeastern Alaska, occurs near sea level in parts of this region and intergrades with bogs (Cooper, 1942; Griggs, 1936). Alpine timberline is at an elevation of approximately 1500 ft in the eastern half of this region, and above this level the vegetation consists of alpine tundra. In the western half of the region alpine tundra intergrades with heath and bogs.

References to Southcentral Alaskan Wetlands

Cooper, William S. 1942. Vegetation of the Prince William Sound region, Alaska, with a brief excursion into post-Pleistocene climatic history. Ecol. Monogr. 12:1-22.

Crow, John H. 1968. Plant ecology of the Copper River Delta, Alaska. Washington State University Ph.D. thesis. 120 p.

Dachnowski-Stokes, A. P. 1941. Peat resources in Alaska. U.S. Dept. Agr. Tech. Bull. No. 769. 84 p.

Griggs, Robert F. 1936. The vegetation of the Katmai district. Ecology 17:380-417.

Hanson, Herbert C. 1951. Characteristics of some grassland, marsh, and other plant communities in western Alaska. Ecol. Monogr. 21:317-378.

Heusser, Calvin J. 1960. Late-Pleistocene environments of North Pacific North America. American Geographical Society Special Publication No. 35. 308 p.

Isleib, M. E. and Brina Kessel. 1973. Birds of the north gulf coast-Prince William Sound region, Alaska. Biol. Pap. Univ. Alaska No. 14. 149 p.

McRoy, C. Peter. 1968. The distribution and biogeography of Zostera marina (eelgrass) in Alaska. Pacific Sci. 22:507-513.

Shacklette, Hansford T. 1961. Substrate relationships of some bryophyte communities on Latouche Island, Alaska. The Bryologist 64:1-16.

Shacklette, Hansford T. 1965b. Bryophytes associated with mineral deposits and solution in Alaska. U.S. Geol. Surv. Bull. 1198-C. 17 p.

Thomas, John H. 1957. The vascular flora of Middleton Island, Alaska. Contrib. Dudley Herbarium 5:39-56.

Pond and lake

Cooper, 1942

Small ponds, an acre or less in area, are found in bogs of undrained hollows in the underlying bedrock surface. Ponds also form in step-like series on gentle slopes, apparently dammed by mats of Carex (especially C. limosa). Aquatic species in the pools are Potamogeton diversifolium, Sparganium angustifolium, and Nymphozanthus polysepalus; emergents along the margins are Hippuris vulgaris and Menyanthes trifoliata.

Crow, 1968

Slightly brackish ponds are common on the Copper River delta. They are discussed in the saline or brackish marsh category.

Dachnowski-Stokes, 1941

Ponds on the lowlands of the Copper River support dense growths of Menyanthes trifoliata with Equisetum spp., Carex spp., and Potentilla palustris. This represents a stage in succession from the open water sloughs and oxbows to a sedge marsh stage.

Near Willow, a series of ponds occupy a small drainageway in a flat plain. The open water is vegetated by aquatic mosses (Hypnaceae), Potentilla palustris, Menyanthes trifoliata, and Nuphar polysepalum. On the margins are rank growths of vegetative Carex aquatilis, C. limosa, and C. rostrata.

Griggs, 1936

Nine species of aquatic plants that were common before the eruption of Katmai have not been seen since then (as of 1930). New ponds are occupied by thick growths of Nymphaea polysepala or Sparganium minimum. Small stagnant ponds without wave action may be fringed with Hippuris vulgaris and Menyanthes trifoliata. Larger ponds with wave action develop a belt of sedges between the open water and the bog margins.

Isleib and Kessel, 1973

There are countless shallow lakes in marshes (mostly on the Copper River delta) along the coast of Prince William Sound. Those nearest the coast may be brackish. They support a relatively uniform vegetation consisting of Hippuris tetraphylla, sedges, Potamogeton filiformis, and Myriophyllum spicatum. With increasing distance from the coast the ponds are deeper and support a more diverse vegetation including Hippuris vulgaris (replacing H. tetraphylla), Sparganium spp., Nuphar polysepalum, and Equisetum spp. Deeper, upland lakes may or may not have emergent plants along the margins.

Thomas, 1957

Inshore from the beach ridges on Middleton Island is a low swampy area with fresh water ponds containing Potamogeton filiformis and Hippuris tetraphylla with margins of Carex lyngbyaei, Polygonum amphibium, P. fowleri, Potentilla egedii, and P. palustris. Common along the margins of brackish water ponds are Carex lyngbyaei and Polygonum amphibium.

Fresh water marsh

Dachnowski-Stokes, 1941

Ponds on the Copper River are colonized by Menyanthes trifoliata in closed stands replaced by stands of Carex lyngbyaei, C. aquatilis, and C. stricta which rapidly build up peat and thereby qualify as bogs. Near Wasilla bogs go through a marsh phase early in their development.

Griggs, 1936

At Katmai sedge marshes form a belt around ponds in which Carex lyngbyaei is dominant and often associated with C. stylosa. Depending on the terrain, the outer fringes of these marshes give way to willow copses, bogs, or even grasslands.

Isleib and Kessel, 1973

Brackish and fresh water marshes are found on the Copper River delta and, to a lesser extent, adjacent to tidal flats near the mouths of streams. Marsh vegetation is composed of Carex lyngbyaei, Deschampsia beringensis, Festuca rubra, Calamagrostis inexpansa, Triglochin maritimum, Eleocharis kamtschatica, and some forbs.

Thomas, 1957

On Middleton Island marshy vegetation occurs on soils of black humus on poorly drained terrain just inshore from beach ridges. These are vegetated with Sphagnum spp., Polypodium vulgare, Calamagrostis spp.,

Carex pluriflora, and others (p. 41).

On poorly drained wave-cut terraces at higher elevations marshes are vegetated with Carex sitchensis, Lysichiton americanum, Caltha palustris, Potentilla palustris, and others (p. 41).

Peatland

Cooper, 1942

Sedge bogs occupy depressions in glacier-scoured rock surfaces and flat areas and some slopes with poor drainage. The peat accumulation is usually 1 to 4 ft deep. The living plant cover is principally a dense turf of sedges with Carex nigricans and C. limosa dominant. Sphagnum moss is relatively abundant, but the substratum is essentially sedge peat. Many areas are transitional between bog and heath. The heaths here, although apparently ecologically equivalent to the heaths of Katmai, lack the regularly spaced water-filled hollows and, except for the dominating Empetrum nigrum, are composed of different species.

Small ponds are frequent in the Carex bogs and support a rather sparse aquatic flora. They form in undrained hollows of the underlying bedrock and in step-like series upon gentle open slopes with walls of hard peat.

There is a general trend for bogs to succeed to forest. The thickening of the heath mat, a thickening of bog deposits, and the slow extinction of the pools lead to a gradual improvment in aeration and subsequent invasion by forest. Conversely, in some areas, especially

where Sphagnum is abundant, the buildup of peat may raise the water table, leading to invasion of forest by bog.

Dachnowski-Stokes, 1941

The bogs of this region are raised (ombrogenous), slope (soligenous), and flat (topogenous). These bogs have usually accumulated 3 to 6 ft of a mixture of sedge and moss peats, but the lower layers of peat profiles tend to be composed of sedges. Often there is a layer of stumps, twigs, and stems of spruce above the bottom sedge peat layer.

Griggs, 1936

The Sphagnum bogs of the Katmai region have a large variety of plants, including a number of grasses and sedges. Myrica gale, Rubus chamaemorus, and Saxifraga hirculus are very characteristic although not especially abundant. These bogs grade into sedge marshes on one hand and grasslands or heaths on the other. No bogs are underlain by more than a foot of peat, but how much peat had accumulated in bogs before the ashfall is unknown.

A heath vegetation type is common at Katmai on poorly drained plains, especially glacial outwash. Empetrum is the dominant species (more species listed on p. 394-5). Absent are Cassiope tetragona, Salix glauca, and Dryas spp. The heath characteristically forms a pattern of steep-sided hummocks and intervening hollows. The hollows are 1 to 3 m across and 1 to 2 m deep, of soft mud, and often paved with loose angular stones. They may fill with water for long periods in wet weather. Vegetation is

sparse or absent on the bottom. The ridges are luxuriantly vegetated and grow higher each year from accumulated plant remains. Griggs considers the heath a permanent subclimax due to lack of drainage.

Hanson, 1951

Hanson discussed upland bogs and described a stand in the Matanuska Valley. This bog is characterized by Andromeda polifolia, Myrica gale, Betula nana, Sphagnum, and other mosses. It is adjacent to a small lake and has a very hummocky surface and standing water in the hollows. Other important species include Potentilla palustris, Vaccinium oxycoccus, Equisetum fluviatile, and Aulocomnium palustre. (More species are given on pages 365-6). This bog is being invaded by Calamagrostis canadensis, Alnus tenuifolius, and Salix spp. indicating the successional trend.

Near Craigie Creek in the Talkeetna Mountains in the vicinity of Palmer, an alpine-sedge marsh at an elevation of 3,100 feet was investigated. Water flows into it from small streams originating on the mountain slopes. Hummocks and ridges, usually aligned at right angles to the slope, are scattered across the surface. Water stands in many of the depressions between hummocks, and in others water oozes out rapidly from the substratum when stepped on. Important species are Eriophorum angustifolium, Carex pluriflora, mosses, Salix reticulata, and Sanguisorba sitchensis. The soil consists of more than 42 inches of peat interspersed with thin layers of silt. No frozen ground was encountered in the upper 42 inches.

Heusser, 1960

Blanket bogs and the blanket-slope intermediate form are especially common in Southcentral Alaska. Raised bogs appear to be rare. Species of the blanket bogs are:

Scirpus caespitosus	Andromeda polifolia
Carex pauciflora	Oxycoccus microcarpus
Cornus canadensis	Drosera rotundifolia
Geum calthifolium	
Empetrum nigrum	

Flat bogs in early stages of development are found in the Katalla, Martin, and Copper river valleys. In the Kenai lowland, later stages occur with Empetrum nigrum, Ledum decumbens, Betula nana, and Sphagnum constituting the principal cover.

Isleib and Kessel, 1973

The substrate of bogs on flats or gentle slopes is sedge-moss peat covered by thick mats of Sphagnum, Carex, Eriophorum, Myrica gale, and ericaceous shrubs. Numerous small ponds have at least some aquatic plants. Species are listed on page 12.

Stream

Griggs, 1936

Pools and muddy banks along rivers are vegetated with Ranunculus hyperboreus. Brooks in poplar forests with pH ca. 7.5 may have several

aquatic mosses (Hypnaceae) as well as _Potentilla palustris_, _Menyanthes trifoliata_, and _Caltha palustris_.

Riparian gravel bar and cutbank

Crow, 1968

In the Copper River delta a _Myrica gale_-_Poa eminens_ community is characteristic of channel levees in a broad belt just inland from the pre-earthquake limit of periodic flooding by brackish water during extreme storm tides. A less widespread community occurring locally on these levees is characterized by _Myrica gale_ and _Hordeum brachyantherum_. Still further inland a _Salix_ spp.-_Festuca rubra_ community is characteristic. The _Salix_ spp.-_Equisetum pratense_ and _Salix_ spp.-_Calamagrostis canadensis_ communities are local on these same sites.

Griggs, 1936

Copses of _Salix alaxensis_, _S. pulchra_, and _S. richardsonii_ occur on river flats at Katmai.

Strand and supratidal meadow

Dachnowski-Stokes, 1941

Sand dunes are dominated by _Ammophila arenaria_ and _Elymus mollis_ with _Lathyrus maritimus_ and _Mertensia maritima_ colonizing seaward portions. On the backslope of dunes, vegetation is _Potentilla fruticosa_, _Spiraea_ sp.,

and Calamagrostis scabra.

Griggs, 1936

Honckenya peploides, Lathyrus maritimus, and Mertensia maritima occupy beaches below extreme high tide. Elymus mollis becomes well established on coastal dunes after they have been built up enough to be beyond the reach of ordinary storms. Inshore from the dunes the Elymus is gradually replaced by a mixture of other grasses and forbs and mosses including Epilobium angustifolium, Polytrichum, Hylocomium, Trientalis europaea, Solidago lepida, Achillea borealis, Galium boreale, Fritillaria camschatcensis, and Calamagrostis scabra.

Hanson, 1951

Supratidal meadows include an Elymus mollis community (stand 35, p. 321 and 323), and an Agropyron trachycaulon-Festuca rubra-Achillea borealis-Lathyrus palustris community (stand 40, p. 325 and 321-322). This community is thought to represent the final stage in the sequence from Elymus dune community to meadow.

Elymus mollis, Arenaria peploides, Mertensia maritima, and Senecio pseudo-arnica grow on sandy and gravelly shores just out of reach of ordinary tides. The Elymus grows thicker as the dunes grow higher, and other species appear, such as Lathyrus maritimus and Poa eminens.

The accumulation of dead roots, litter, and material deposited by floods creates a soil that permits more and more species to move in. Intermediate communities which might be grouped into an Elymus-Festuca-

Calamagrostis-forb class are: Elymus mollis-Festuca rubra (stand 7, p. 321-3); Elymus mollis-Calamagrostis canadensis (stand 14, p. 321-4); and Calamagrostis canadensis-Festuca altaica-Elymus mollis (stand 5, p. 321-322, 324). The final herbaceous stage is probably similar to the Agropyron trachycaulon-Festuca rubra-Achillea borealis-Lathyrus palustris community mentioned above (stand 40, p. 321-2, 325). Willows are usually the next invaders of these meadow communities. Other stands in the supratidal meadow category include a Lupinus nootkatensis-Lathyrus maritimus-Achillea borealis-Poa pratensis-Festuca rubra community (stand 23, p. 321-2, 324) and Calamagrostis canadensis community (stands 22A, 22B, p. 325).

Shacklette, 1961

Four bryophyte species grow in areas periodically inundated by tides on Latouche Island. They are Grimmia maritima, Eurhynchium praelongum, Mnium glabrescens, and Scapania undulata. These grow in crevices of slate or graywacke. Six bryophyte species grow on rocks near salt water but beyond the influence of waves and tides (p. 12). [Other bryophyte species known from similar habitats throughout Alaska are listed in Shacklette, 1965b].

Thomas, 1957

Common species on top and both sides of beach ridges are Elymus arenarius, Honckenya peploides, Mertensia maritima, and Senecio pseudo-arnica. More species are listed on page 41.

ialine or brackish marsh

Crow, 1968

The Copper River delta is a mosaic of stream channels, levees adjacent :o the channels, and low interchannel basins dotted with numerous ponds. These three landforms are illustrated diagramatically in figure 5.] 'our vegetation belts are discernible on the delta progressing from the ea inland. They are named after the characteristic levee vegetation of 'ach and are: 1) Hedysarum-Deschampsia belt; 2) Myrica-Poa belt; 3) Salix-estuca belt; 4) Alnus or Picea belt. Prior to the Good Friday earthquake 'f March 27, 1964, which raised this part of the coast 1.89 m, the entire iedysarum-Deschampsia belt was periodically flooded by brackish water luring storm tides, but now it is never affected by sea water. The vege-ation has started to respond to the resultant desalinization and decrease n pH, but the basic vegetation patterns described here still reflect pre-'arthquake conditions.

In the Hedysarum-Deschampsia belt the characteristic vegetation of the evee tops is a community dominated by Hedysarum alpinum and Deschampsia eringensis. A less extensive community that occurs locally in sandy oils of levee tops is characterized by Hedysarum alpinum and Equisetum ariegatum.

Two channel bank communities occur within the Hedysarum-Deschampsia elt: pure Carex lyngbyaei at the base and Carex lyngbyaei-Eleocharis amtschatica between the pure Carex and the Hedysarum-Deschampsia com-unity of the levee tops. Under pre-earthquake conditions the Carex

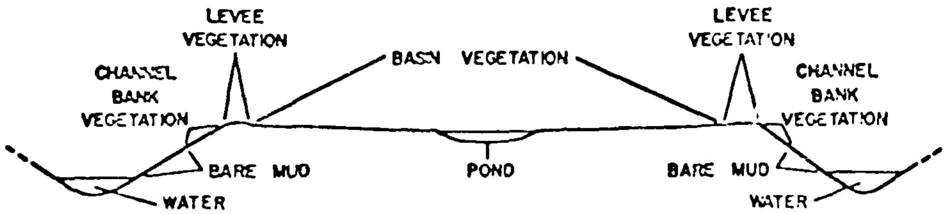


Figure 5. Cross-sectional diagram of the Copper River delta showing the positions occupied by different kinds of vegetation. (From Crow, 1968, figure 3, p. 10.)

community, or at least the lower part of it, was normally flooded twice daily by brackish water. On the basins between channel levees (exclusive of ponds) are three communities dominated by *Carex lyngbyaei*: 1) *Carex lyngbyaei-Lathyrus palustris*; 2) *Carex lyngbyaei-Triglochin maritima*; 3) *Carex lyngbyaei-Cicuta mackenzieana*. (1) and (2) are both wet, but (2) is slightly less well drained and has fewer species; (3) was found in very poorly drained sites or along drainageways and also in both peat and mineral soils of shallow ponds. [The relative positions of the channel bank and levee communities are shown diagrammatically in figure 6.]

Ponds are abundant in the low basins between channels in the *Hedysarum-Deschampsia* belt. These ponds are deepest toward the west (windward) edge of each pond and shallowest toward the east edge, apparently due to wind-caused wave action eroding the leeward bank and depositing the eroded material on the bottom. Three types of ponds are recognizable on the basis of peat accumulation -- very little, intermediate amounts, and a great deal. Ten different communities grow in these ponds and are summarized as follows:

1) *Potamogeton* (*P. filiformis*) occurs in water deeper than ca. 44 cm in ponds with little or intermediate and possibly also with much peat accumulation. (*Chara* sp. is also present in intermediate peat ponds.)

2) *Potamogeton-Myriophyllum* (*P. filiformis*, *M. spicatum*) grows in 34 to 43 cm of water in ponds with little peat and (with the addition of *Chara* sp.) in approximately the same depths in ponds with intermediate peat.

3) *Myriophyllum-Festuca* (*M. spicatum*, *Potamogeton filiformis*, *F. elatior*) replaces community (2) in water of about the same depth as (2)

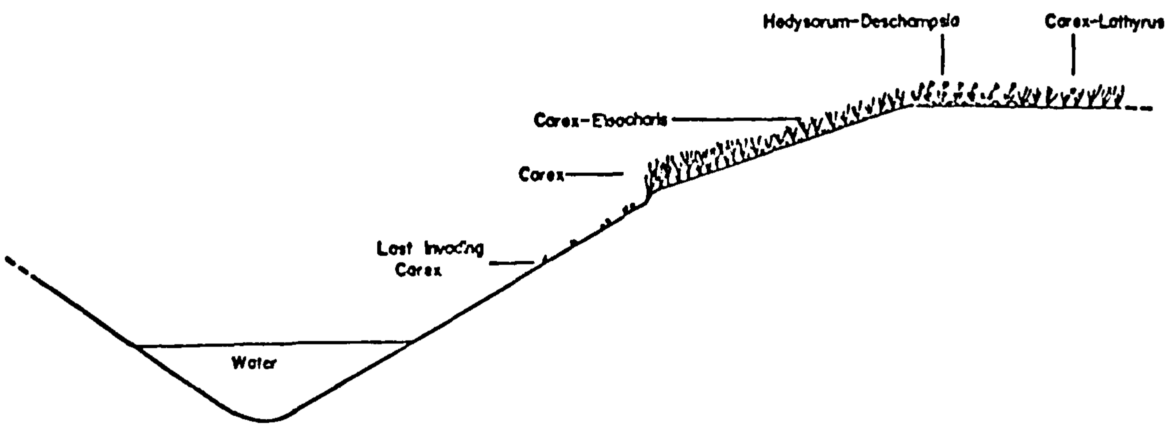


Figure 6. Cross-sectional diagram showing zones of plant communities adjacent to a channel on the Copper River delta. (From Crow, 1968, figure 4, p. 12.)

in ponds with much peat accumulation.

4) Myriophyllum-Potamogeton (M. spicatum, P. filiformis, Chara sp.) grows in the shallower part of the zone occupied by (2) in ponds of intermediate peat and much peat.

5) Myriophyllum-Eleocharis (M. spicatum, E. mamillata, Potamogeton filiformis) grows in ponds with much peat in water depths intermediate to (3) and (4).

6) Potamogeton-Hippuris (P. filiformis, H. tetraphylla, Myriophyllum spicatum) grows in 23 to 37 cm of water in low and intermediate peat ponds.

7) Hippuris-Potamogeton (H. tetraphylla, P. filiformis, M. spicatum) grows in 16 to 24 cm of water in ponds with low and intermediate peat.

8) Carex-Potamogeton (C. lyngbyaei, P. filiformis, H. tetraphylla, M. spicatum) replaces (6) and (7) in ponds with much peat.

9) Carex-Hippuris (C. lyngbyaei, H. tetraphylla) grows in 0 to 15 cm water in ponds of little and intermediate peat.

10) Carex-Cicuta (Carex lyngbyaei, Carex mackenzieana) replaces (9) in ponds with much peat accumulation.

[A chart showing the relationship of these communities to depth of water in the pond and the successional relationships of these communities with increasing peat formation in the ponds, is reproduced in figure 7.]

Since the earthquake a number of changes in substrate and species distribution have occurred. Soil samples taken in 1967 show marked desalinization and decreased pH compared to 1964 values. The original vegetation of the channel banks is being replaced by certain species from the Hedysarum-Deschampsia communities of the levee tops. Drastic

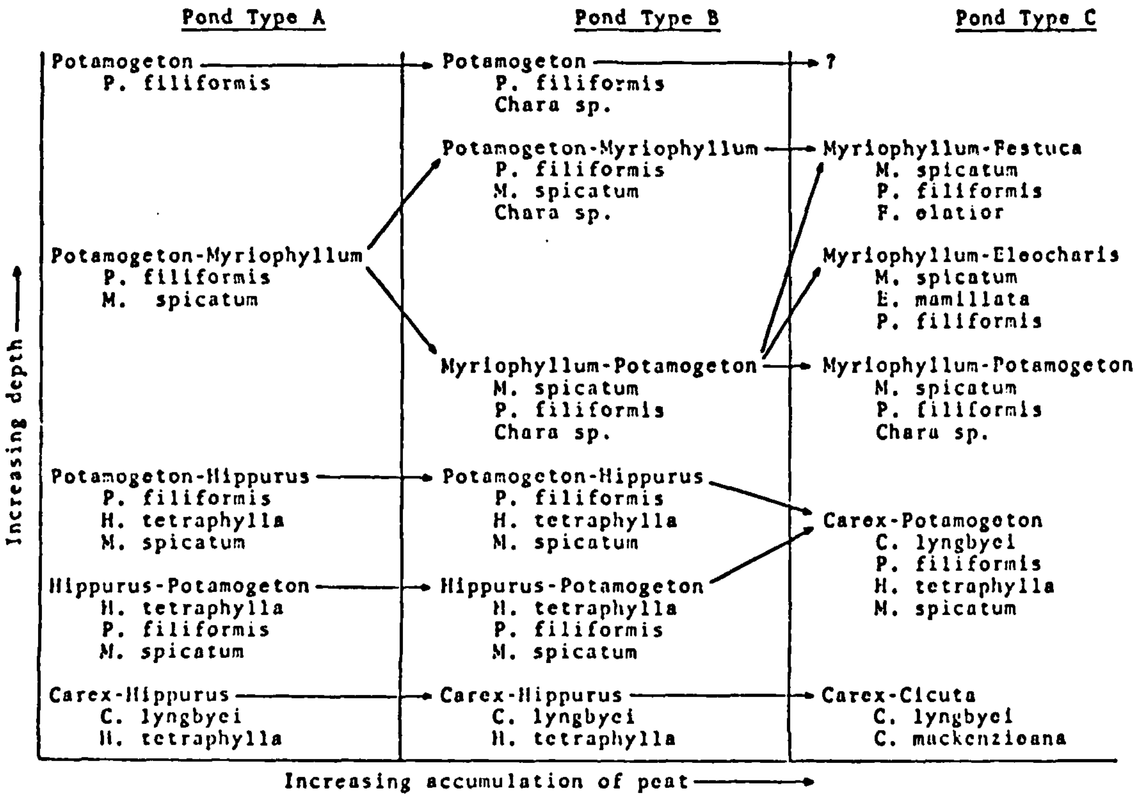


Figure 7. Three types of ponds on the Copper River delta with progressively greater accumulations of peat. Hypothetical successional sequences of the communities are shown. Species present are listed in ascending order of dominance. (From Crow, 1968, figure 13, p. 51.)

changes are occurring in the Hedysarum-Deschampsia communities including a decrease in the cover of the dominant species by 35% to 44%. The basin vegetation is changing at a much slower rate. At the same time the three inland levee communities are advancing seaward.

Tidal flats exist seaward of the Hedysarum-Deschampsia belt. Before the earthquake these were usually covered with sea water and were unvegetated. They end abruptly landward at a 1-m-tall cutbank at the edge of the marsh. Presently high tides cover the flats, but for a much shorter time than previously. A Puccinellia nutkaensis-dominated vegetation is developing on the flats.

Griggs, 1936

Salt marshes consist almost entirely of Puccinellia paupercula at Katmai. Triglochin palustris and Atriplex cf. alaskensis are found growing with the Puccinellia, but these taxa are rare.

Hanson, 1951

A marsh of Festuca rubra-Poa palustris-forbs (stand 39, p. 321-3, 326) occupies broad depressions behind beach ridges that are not now flooded by high tides but remain wet late in the spring.

The eastern part of the Goose Bay estuary has steep banks that are being actively eroded by waves and tides, but the western part of the estuary is undergoing deposition. Well-developed zones in the estuary are: 1) Puccinellia pyryganodes-Salicornea herbacea-Suaeda maritima community closest to the water (p. 329). It has a fine silt substrate and

is subject to frequent tidal submersion. 2) Plantago juncoides-Puccinellia triflora-P. glabra (stand 15, p. 328-9) grows about two feet above ordinary high tides where surface drainage is fairly good. 3) Triglochin maritima-Potentilla pacifica (stand 57, p. 328-30) is on slightly higher land with a firm, fine silt substrate that is fairly well drained. 4) Carex ramenskii-Triglochin maritima-Potentilla pacifica (stand 58, p. 328, 330) is in a setting more poorly drained and wetter than (3) and probably less brackish. 5) Carex pluriflora-C. cryptocarpa (stand 59, p. 328, 330) is wetter than (4). 6) Carex cryptocarpa (stands 41, 26A, 26B, p. 328, 330-2) is wetter and more poorly drained than (5) with much standing water present. 7) Calamagrostis canadensis-Myrica gale (p. 332) is wet and poorly drained. Myrica forms tussocks or hummocky areas since its stems grow first horizontally and then ascend. Other estuarian communities include: Carex cryptocarpa-Calamagrostis canadensis (stand 11, p. 328, 332) one half mile from high tide line; Juncus balticus (stand 12, p. 328, 333); and Calamagrostis canadensis (stand 13, p. 328, 333). Zonation of such silty tidal areas at Knik arm and near Homer is similar in basic outline (p. 334-5).

Thomas, 1957

Carex lyngbyaei and Polygonum amphibium are common along the margins of brackish ponds on Middleton Island.

Intertidal zone

McRoy, 1968

Many *Zostera marina* beds are found in Prince William Sound, though their distribution has been altered by the 1964 earthquake. *Zostera* is also present in several bays on Kodiak and Afognak islands. It is apparently absent from the outer coast of the Kenai Peninsula and Cook Inlet, probably because of turbidity and strong currents. It is also rare or lacking along the coast east of Prince William Sound because most of this coast is rugged and exposed to the sea, and the few bays are fed by glaciers or glacial streams. It has been reported only from Yakutat Bay in this section of coast.

Vegetation maps

Maps showing the distribution of forest, alder, and willow in two areas of Prince William Sound are found in Cooper (1942, p. 12, figure 9 and p. 14, figure 12). Maps showing the distribution of forest and bog are found in Dachnowski-Stokes (1941) for the following areas:

Bomb Point (p. 41, figure 14)

Gravina Point (p. 43, figure 16)

Foreland between Port Gravina and Port Fidalgo (p. 45, figure 18)

ALEUTIAN ISLANDS

The Aleutian Islands form an arcuate chain stretching approximately 1400 mi into the North Pacific. They are primarily of volcanic origin; and 57 volcanoes of Quaternary age, 27 of them reported active, occur on the islands. The islands without volcanoes appear to be emerged parts of tilted fault blocks consisting mostly of Cenozoic volcanic rocks (Wahrhaftig, 1965). Three main types of topography are found: 1) wave-cut platforms less than 600 ft above sea level, bordered by low sea cliffs; 2) intensely glaciated mountains 600-3000 ft above sea level, indented with fjords and bordered by cliffs as high as 2000 ft; and 3) the volcanoes, of which the highest bear ice caps or small glaciers.

No permafrost is present in this region. Streams are short and swift, many plunging into the sea over waterfalls. Small lakes are present in irregular ice-carved basins on the glaciated islands (Wahrhaftig, 1965). Extreme high and low tides are of relatively low amplitude, 5 ft above and 1.5 ft below mean sea level possibly being representative. However, higher extreme tides, up to 13 ft above and 3.5 ft below mean sea level occur on the Alaska Peninsula (Johnson and Hartman, 1969).

Sea ice extends to the north side of the Alaska Peninsula each winter but does not form around any of the Aleutian Islands, although remnant ice is occasionally blown there (Johnson and Hartman, 1969).

The climate of this region is very maritime, being cool, stormy, and cloudy throughout the year. The average annual temperature ranges from 35° to 40° F (Johnson and Hartman, 1969). At Amchitka Island the average

monthly temperature ranges from 32° F in January and February to 48° F in August (Shacklette *et al*., 1969). Average annual precipitation varies from 160 inches on a small area of the Alaska Peninsula to 28 inches on Shemga Island. Most of the region receives 35 to 70 inches annually (Viereck and Little, 1975).

The most characteristic vegetation of the Aleutians is a heath that mantles lowlands and gently undulating slopes. At higher elevations it becomes discontinuous, apparently in response to an abrupt increase in intensity and duration of winds (Shacklette *et al*., 1969). No trees grow in this region, except in two or three locations where a few individuals of Sitka spruce have been planted. Even erect shrubs are lacking or very rare, the woody plants normally growing prostrate and entangled in the vegetation mat with herbs, mosses, and lichens.

References to Aleutian Island Wetlands

Amundsen, C. C. 1972. Amchitka Bioenvironmental Program: Plant ecology of Amchitka Island, Final Report. Batelle, Columbus Laboratories, under AEC Prime, Contract No. AT(26-1)-171. 27 p.

Amundsen, C. C. and E. E. C. Clebsch. 1971. Dynamics of the terrestrial ecosystem vegetation of Amchitka Island, Alaska. Bioscience 21:619-623.

Bank, Theodore P., II. 1951. Botanical and ethnobotanical studies in the Aleutian Islands I. Aleutian vegetation and Aleut culture. Michigan Acad. Sci., Arts, and Letters Papers 37:13-30.

Hulten, Eric. 1960. Flora of the Aleutian Islands, 2nd ed. J. Cramer, Weinheim. 376 p.

McRoy, C. Peter. 1968. The distribution and biogeography of *Zostera marina* (eelgrass) in Alaska. Pacific Sci. 22:507-513.

Shacklette, Hansford T. 1965b. Bryophytes associated with mineral deposits and solutions in Alaska. U.S. Geol. Surv. Bull. 1198-C. 17 p.

Shacklette, Hansford T. and others. 1969. Vegetation of Amchitka Island, Aleutian Islands, Alaska. U.S. Geol. Surv. Prof. Paper 648. 66 p.

Walker, Egbert H. 1945. Plants of the Aleutian Islands, p. 63-71. *In* Collins, H. B., Jr., A. H. Clark, and E. H. Walker, The Aleutian Islands: their people and natural history. Smithsonian Inst. War Background Studies 21, Publ. 3775.

Pond and lake

Amundsen, 1972; Amundsen and Clebsch, 1971

Ephemeral pools are usually dominated by Juncus balticus, Alopecurus aequalis, Sparganium hyperboreum, or Caltha palustris.

Hultén, 1960

Lakes are comparatively rare and are very sparsely vegetated. A few aquatic plants such as Potamogeton perfoliatus, Myriophyllum spicatum, Sparganium hyperboreum, Ranunculus tricophyllus, Hippuris vulgaris, and Isoetes braunii usually occur singly or in patches.

Shacklette et al., 1969

Two kinds of lakes occur on the low plateaus of Amchitka Island. Those with an origin related to geologic structure are relatively deep with a bedrock or cobble bottom. Those that develop on undulated surfaces of old, elevated marine platforms are shallow and have a muck or soil bottom. With few exceptions only the latter kind of lake contains emergent or immersed bottom-rooted vascular plants. These form two communities: Hippuris vulgaris-Ranunculus trichophyllus and Isoetes muricato-Ranunculus-reptans-Limosella aquatica (both described in detail on p. 23).

Pools form in depressions of the vegetation, bedrock or colluvium, and peat mantle of the Empetrum heath. Three plant communities grow in these pools: Juncus triglumis-Eriophorum russeolum, Subularia aquatica-Callitriche anceps, and Siphula ceratites-Scapania paludosa.

Walker, 1945

Lakes and ponds are common on many islands. The principal submerged aquatics are Potamogeton alpinus, Myriophyllum spicatum, Hippuris vulgaris, and Sparganium hyperboreum.

Fresh water marsh

Bank, 1951

Flat areas generally receive water from surrounding slopes. These seldom have standing water but are continually wet. Common in such situations are Platanthera hyperborea, P. dilatata, and P. tipuloides (the latter principally in the western Aleutians).

The vegetation of true marshes varies according to the amount of standing water present. Typically present are Polygonum viviparum, Eriophorum medium, Carex rariflora, Scirpus caespitosus, Iris setosa, and Geum calthifolium.

Hultén, 1960

The zonation in marshy areas surrounding ponds is: 1) pond margin, pure Carex lyngbyaei; 2) above this on drier ground (but still marshy) is Carex pluriflora as the primary species with sparse C. anthoxanthea, Plantago macrocarpa, and Erigeron peregrinus secondary. This uppermost marsh zone grades to a drier community composed of fragments of subalpine meadow and Calamagrostis canadensis which is replaced by Empetrum heath at yet higher elevations.

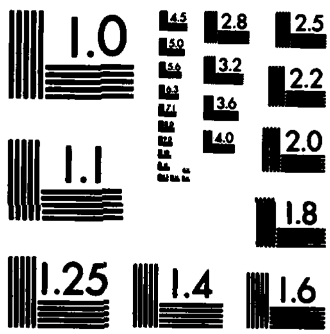
Shacklette *et al.*, 1969

The first two communities [listed here as marshes] are considered bogs by Shacklette. He differentiated them from marshes on the basis of their bryophytic-dominated vegetation and the fact that they are odorless when disturbed. Nevertheless, these communities occur on mineral substrates. A *Philonotis americana-Parnassia kotzebuei* community occurs on very gentle slopes where water moves through the saturated inorganic substrate. A *Scapania paludosa-Nardia scalaris-Marsupella emarginata* community occupies drainage channels and wet areas, but only at altitudes above 4000 ft. The primary species also grow in the snow-bed community (discussed below) but are there associated with different species of vascular plants.

The next two communities are considered marshes by Shacklette. They have a preponderance of sedges and forbs and give off a strong odor of hydrogen sulfide when stirred up, even in winter. A wet sedge-meadow community typically occurs at the borders of lakes but also develops on very wet slopes and beside streams in the *Empetrum* heath. Characteristic species are *Carex lyngbyaei*, *C. pluriflora*, *C. anthoxanthea*, *C. macrochaeta*, *Eriophorum russeolum*, and *Juncus triglumis*. A *Caltha palustris-Claytonia sibirica* community occurs most commonly on wet, inorganic substrates that have enough water moving through them to prevent freezing in winter.

A snow-bed community occurs in mountain valleys along the margins of small streams derived from melting snow. Characteristic species are *Anthelia julacea*, *Scapania paludosa*, *Saxifraga hirculus*, and *leptarrhena pyrolifolia* (p. 31).

AD-A120 573 A LITERATURE SURVEY ON THE WETLAND VEGETATION OF ALASKA 2/3
(U) ALASKA UNIV FAIRBANKS INST OF ARCTIC BIOLOGY AND
MUSEUM A R BATTEN ET AL. AUG 82 WES-TR-Y-82-2
UNCLASSIFIED DACW39-76-M-2473 F/G 8/6 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Peatland

In this region of Alaska it becomes more difficult to separate the fresh water marsh from the bog categories, and the nomenclature of these types of sites has become somewhat confusing. Heath vegetation, dominated by Empetrum nigrum, is characteristic of the Aleutians and is underlain in most places by a layer of peat 30-420 cm or more thick. The wetter parts of this heath are treated here as peatlands.

Amundsen, 1972; Amundsen and Clebsch, 1971

The lowland tundra is a "wet meadow" with sedges and lichens more prominent in the wetter areas and grass and subshrubs more prevalent in drier areas. The substrate is mostly a sedge-lichen peat, 30 to 60 cm deep on moderate slopes and up to 420 cm deep on lower slope transitions. It is dotted with ponds and shallow lakes underlain by peat.

The lowland tundra can be divided into three wet lowland community types, in addition to "ephemeral pools" [see figure 8]. 1) Breakaway tundra is the wettest of the three. It is a very fragile vegetation dominated by sedges and lichens (particularly Cladonia pacifica) that "breaks away" when walked on. 2) Sedge-lichen meadow is similar to the breakaway tundra but contains enough rooted plants (grasses and sedges) to stand up under light foot traffic. 3) Crowberry-sedge-grass meadow (Empetrum nigrum-Carex spp.-Calamagrostis nutkaensis) is the driest of the three lowland communities. With increasing elevation and drainage it grades into the crowberry-grass-sedge meadow of the uplands.

Bank, 1951

Boglike areas are common throughout the Aleutians on the sides of hills both at lower altitudes and in the alpine regions. These are seepage slopes, with water essentially oozing underground draining from the hills above. The vegetation consists mainly of mosses (including *Sphagnum*) and liverworts (species list p. 23). Floating *Sphagnum* mats are not to be found.

Hultén, 1960

Real *Sphagnum* bogs were not observed in the Aleutian Islands. However, an association of *Rubus chamaemorus*, *Empetrum nigrum*, *Vaccinium uliginosum*, *V. vitis-idaea*, *Carex rariflora*, mosses including *Sphagnum*, and lichens does occur.

Shacklette *et al.*, 1969

Most bogs on Amchitka are soligenous and occur on gentle to moderate slopes. A *Sphagnum* bog community occurs and is best developed in seepage channels or broader areas of gentle slope. This community intergrades in places with wet sedge meadows. The borders of lakes and pools do not support bogs.

[Shacklette considered two other communities as bog communities because they are dominated by bryophytes, but they are treated here in the fresh water marsh category because they occur on mineral soils.]

In addition to the *Sphagnum* bog, three communities are characterized by saturated peaty substrates: 1) The *Empetrum-Carex-lichen* community is

characteristic of slopes and summits of low ridges and is commonly hummocky, interdigidated with ecotonal variants, and interrupted by pools and lakes. The substrate is a fibrous peat from a few cm to 60 cm thick and is saturated with water throughout the year. Characteristic species are Empetrum nigrum, Carex pluriflora, C. macrochaeta, Cladonia pacifica, and Sphaerophorus globosus.

2) The Cladonia-Carex meadow community occurs adjacent to the Empetrum Carex-lichen community and merges with it. It is normally located on more level areas or on the lower parts of gentle slopes and is therefore wetter than the Empetrum-Carex-lichen community. Characteristic species are Cladonia pacifica, Carex lyngbyaei, and C. macrochaeta.

3) A small, artificially created community is the peat bank community, formed by excavations related to military operations during World War II. These disturbed sites have been invaded by plants adapted to a saturated organic substrate, strong winds, and full exposure to light. These plants are mostly bryophytes and a few lichens. Characteristic species are Pogonatum alpinum, Polytrichum commune, Cephalozia bicuspidata, and Dicranella heteromalla.

Stream

Bank, 1951

Fontinalis neomexicana, Ranunculus aquatilis, and Myriophyllum spicatum are found in streams.

Shacklette _et_ _al_., 1969

Most streams are narrow, swift, and short. For the most part they flow at a fairly steady rate, except for periods of greatly increased flow following heavy rainfall and snow melt. They are deeply entrenched in the vegetation and peat mantle and have a bedrock, gravel, or colluvium channel bottom. They appear to have become entrenched by the growth and deposition of vegetation at their margins (as opposed to being erosional). Characteristic plants are _Fontinalis_ _neomexicana_ and _Ranunculus_ _trichophyllus_.

Riparian gravel bar and cutbank

Though gravel bars may occasionally occur on major streams in some parts of the Aleutians, their vegetation has not been described in the literature. The vegetation described below occurs mostly on peaty substrates adjacent to small streams or on peat cutbanks above entrenched streams.

Bank, 1951

Streptopus _amplexifolius_, _Linnaea_ _borealis_, _Juncus_ _balticus_, grasses, ferns, _Carex_ spp., _Veratrum album_ and _Veronica_ _americana_, the last two especially in the western Aleutians (p. 20), grow along stream margins.

Shacklette _et_ _al_., 1969

The narrow, deeply entrenched streams of gentle slopes and valleys support a distinctive plant community that is especially conspicuous in

June, when the bright green of the stream-side plants contrasts strongly with the brown tones of the adjacent Cladonia-Carex meadows. An understory of forbs, bryophytes, and lichens adapted to reduced light grows on the steep stream banks. Characteristic species are Athyrium filix-femina, Carex lyngbyaei, Heracleum lanatum, Geum macrophyllum, and Dryopteris dilatata.

Strand and supratidal meadow

Amundsen, 1972; Amundsen and Clebsch, 1971

A diffuse community of decumbent succulent herbs occurs between the Elymus zone and the mean high tide mark. Principal species are Senecio pseudo-arnica, Mertensia maritima, Honckenya peploides, and Lathyrus maritimus.

A grass community occurs above the high tide line on beaches and on small islets off the coast and on some of the larger seastacks. Elymus arenarius is dominant in these stands, but Festuca rubra and Poa eminens are also common.

Bank, 1951

Seaward of the Elymus zone are scattered growths of Cochlearia officinalis and Lathyrus maritimus as well as a few grasses.

Sea cliffs and soil patches among beach boulders contain growths of Pohlia cruda, Plagiothecium roseanum, Brachythecium albicans, Poa spp., Potentilla villosa, P. nana, P. palustris, and Saxifraga bracteata.

Grass hummocks dominated by Elymus arenarius are found on Aleutian beach slopes. A number of other plants are associated with the Elymus (p. 20).

Shacklette et al., 1969

A Honckenya peploides-Senecio pseudo-arnica community occurs on shorelines of sand, pebbles, or cobbles. The Senecio may grow as tall as 1.5 m and be so closely spaced that passage through the community is difficult. Abundant driftwood in this community indicates that it is submerged in sea water from time to time.

The Elymus arenarius community grows on sandy beaches, old terraces, and on the tops of sea cliffs 25 to 100 ft above sea level. On dunes of dark-colored sand, pebbles, and cobbles there is a community of Rhacomitrium lanuginosum-Schistidium apocarpum-Ulota phyllantha.

Amchitka Island is almost completely bordered with precipitous sea cliffs of andesite, breccia, and other igneous rocks. These range from a few to 100 ft above the sea. Four communities grow in these cliffs, but one is limited to sites too high and dry to qualify as wetlands. The other three communities are: 1) On beach boulders, rock pinnacles, and cliff faces to the very cliff summits is a Eurhynchium praelongum-Puccinellia langeana-Caloplaca granulosa community. These species have a great tolerance to salt water. Furthermore the moss and the grass grow very luxuriantly where manured by birds. 2) The Potentilla villosa-Draba hyperborea-Saxifraga bracteata community grows in rock crevices from 10 ft above the sea to the tops of cliffs. 3) The Xanthoria candelaria-

Ramalina scoparia-R. almquistii community occurs near the summits of high cliffs and offshore sea stacks.

Intertidal zone

Bank, 1951

Reefs of wave-cut basalt supporting abundant edible algae extend from every point of land and are also present in many of the bays.

McRoy, 1968

Zostera marina grows in shallow waters in bays on the Alaska Peninsula and on the Aleutian Islands as far west as Atka and Adak islands. The plants on Adak Island are evidently the result of transplantation experiments by the U.S. Fish and Wildlife Service. *Zostera* is apparently lacking in the western Aleutian Islands probably because of a lack of protected bays. The *Zostera* beds in Izembek Lagoon on the Alaska Peninsula are the largest known single stand of this species.

Walker, 1945

Clear cold water, rocky bottoms, surging waves, and strong currents are ideal for seaweeds, and they are found in great luxuriance. They cover the rocks from high tide level down to 40 fathoms. The alga *Fucus* grows around the low tide level; from well below low tide to a depth of many fathoms are kelps, the most common being *Alaria*; *Ulva* is common in quiet waters and on less rocky or even muddy bottoms.

Zostera marina is common along seacoasts where there are muddy bottoms

and quiet waters.

Succession in general

Amundsen, 1972; Amundsen and Clebsch, 1971

Long term successional changes are not unindirectional. The constantly changing drainage, resulting from peat accumulation and movement, causes long-term alternate drying and swamping over local areas and precludes local stability. The overall vegetation of the island will change little in time but may change considerably in space.

Vegetation maps

We are aware of no vegetation maps for this region. However, Bank (1951) provides diagrammatic cross sections illustrating topography and vegetation of two main types of island [reproduced here as figure 9].

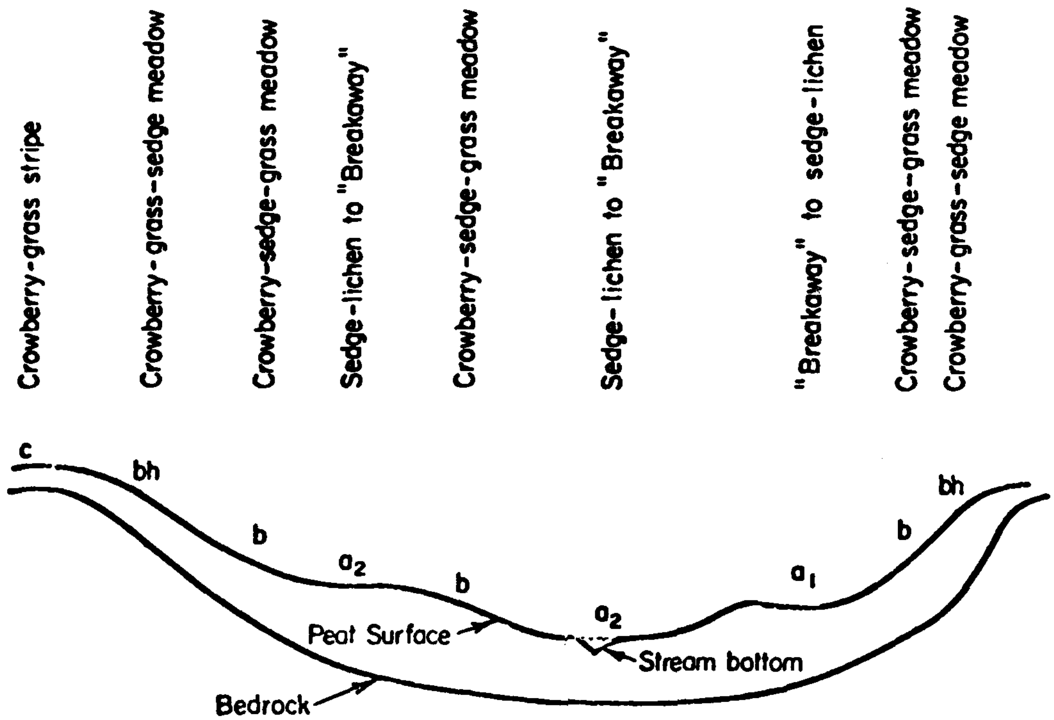


Figure 8. A modal soil-depth profile through an upland tundra-lowland tundra transitional basin on Amchitka Island. The vertical exaggeration is about ten to one. The maximum depth represented is 3 m; the width of the area is about 365 m. (From Amundsen, 1972, figure 2, p. 13.)

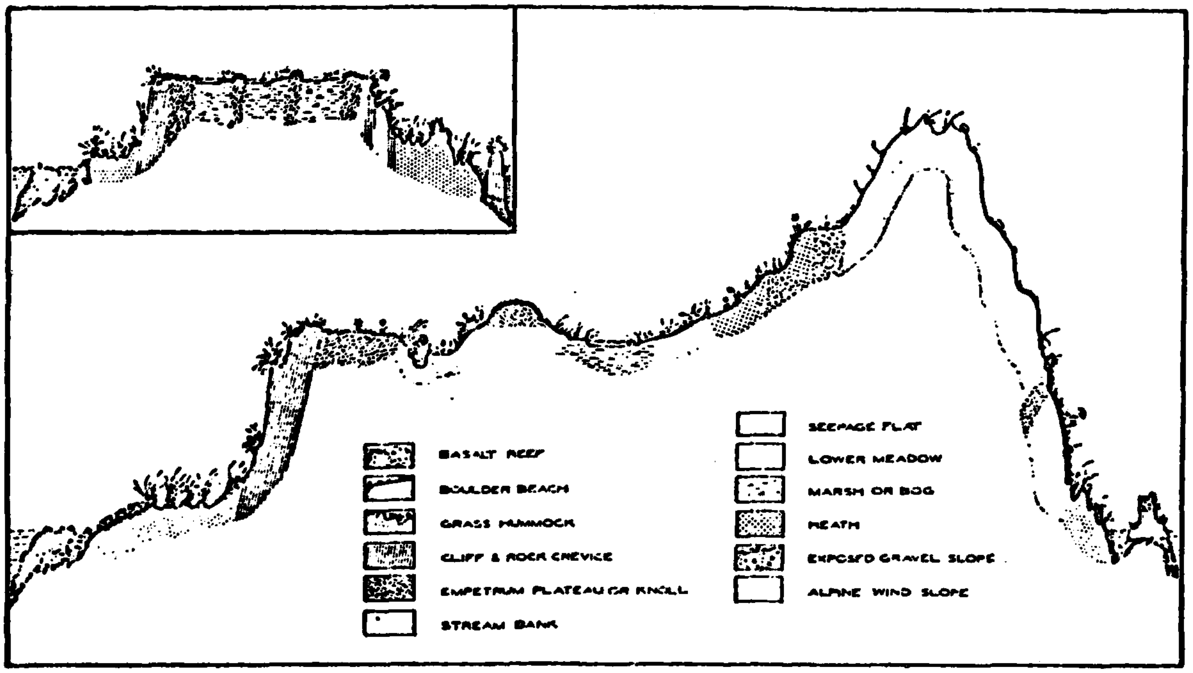


Figure 9. Diagram representing the topographic relations of the chief habitats on the two main types of island in the Aleutian chain, namely, the plateau island (inset) and the mountainous island. The physiognomy of the vegetation is hinted at by the marginal profile. Adjacent to each part of the profile is a symbolic indication of the corresponding plant association or community. (From Bank, 1951, figure 1, p. 18.)

BERING SEA ISLANDS

These islands rise abruptly from a shallowly submerged submarine plain. Most of the islands are rolling uplands a few hundred to 1000 ft high bordered by wave-cut cliffs (Wahrhaftig, 1965). Rivers are small and short and largely confined to St. Lawrence and Nunivak islands. Most of the smaller islands have no permanent streams. Permafrost is widespread and thaw lakes are abundant on the lowlands of St. Lawrence and Nunivak islands. There are no glaciers on any of these islands (Wahrhaftig, 1965; Viereck and Little, 1975). Tide range is small; extreme tides range from 2.5 to 5 ft above and 0.5 to 1.5 ft below mean sea level (Johnson and Hartman, 1969). Pack ice surrounds St. Lawrence and Nunivak islands each winter and sometimes extends or is blown south nearly to the Aleutians (Johnson and Hartman, 1969).

The climate of this area is classified as transitional between arctic and maritime. The average annual temperature is quite low on the more northern and eastern islands, ranging from 30° F on Nunivak Island to 27° or 25° F on St. Lawrence Island (Johnson and Hartman, 1969). The Pribilof Islands are somewhat warmer. Precipitation varies from approximately 24 to 16 inches annually, decreasing from south to north (Viereck and Little, 1975). During late summer and autumn, violent storms, usually from the southwest, may last for days or weeks at a time (Young, 1971).

The vegetation of these islands is variable. That of the Pribilofs is primarily a heath mat similar to that of the Aleutians (Merriam, 1892) but the vegetation of St. Lawrence Island is primarily tundra, similar to that of the Arctic Slope where sedges and grasses predominate.

References to Wetlands of Bering Sea Islands

Bos, Gregory N. 1967. Range types and their utilization by muskox on Nunivak Island, Alaska: a reconnaissance study. University of Alaska M.S. thesis. 124 p.

Fay, F. H. and T. J. Cade. 1959. An ecological analysis of the avifauna of St. Lawrence Island, Alaska. Univ. Calif. Publ. Zool. 63:73-150.

Klein, David R. 1958. Saint Matthew Island reindeer-range studies. USDI Fish and Wildlife Service, Federal Aid in Wildlife Job Completion Report, Project W-3-R-12, Work plan B, Job No. 6. Juneau, Alaska. 39 p.

McRoy, C. Peter. 1968. The distribution and biogeography of *Zostera marina* (eelgrass) in Alaska. Pacific Sci. 22:507-513.

Palmer, Lawrence J. and Charles H. Rouse. 1945. Study of the Alaska tundra with reference to its reactions to reindeer and other grazing. USDI Fish and Wildlife Service, Research Report 10. 48 p.

Rausch, Robert L. and Virginia R. Rausch. 1968. On the biology and systematic position of *Microtus abbreviatus* Miller, a vole endemic to St. Matthew Island, Bering Sea. Z. f. Saugetierkunde 33:65-99.

Young, Steven B. 1971. The vascular flora of St. Lawrence Island with special reference to floristic zonation in the arctic regions. Contr. Gray Herb. Harvard University No. 201. 115 p.

ınd and lake

Bos, 1967

Nunivak Island has many small shallow ponds and lakes. The most ommon species are Hippuris vulgaris, Ranunculus pallasii, and Carex ıuatilis.

Klein, 1958

Hippuris vulgaris, Equisetum palustre, and Potamogeton sp. grow in ıkes and ponds; Potentilla palustris and Ranunculus hyperboreus are found ong lake shores on St. Matthew Island.

Rausch and Rausch, 1968

Arctophila fulva grows abundantly in pond margins on St. Matthew land.

Young, 1971

Although a large proportion of the surface of St. Lawrence Island is vered by fresh water lakes and ponds, the aquatic flora is sparse and ny of the tundra ponds contain no true aquatic plants. The shallow ges of ponds usually support a dense growth of semi-aquatic species ch as Arctophila fulva, Eriophorum angustifolium, and Carex aquatilis. ue aquatic species are Ranunculus hyperboreus, R. pallasii, Potentilla lustris, and Hippuris vulgaris.

Fresh water marsh

Klein, 1958

Floodplains adjacent to large lakes on St. Matthew Island are inundated every one to five years by storm tides flooding the beach dikes or by exceptional spring runoff. The rich alluvial soils in these areas support a lush growth of grasses and some forbs and willows. *Deschampsia caespitosa* is the dominant grass, often forming pure stands; *Salix arbutifolia* and *Rumex fenestratus* are common.

Rausch and Rausch, 1968

Wet areas in the lowlands on St. Matthew Island with gravelly loam soils support *Poa leptocoma*, *Carex lachenalii*, *C. nesophila*, and *Primula tschuktschorum*.

Peatland

Bos, 1967

Wet tundra covers about 57.5% of Nunivak Island. West of Nash Harbor this type occupies the tops and upper slopes of flat-topped ridges. Peat mounds here are small and there are relatively few water bodies. This type is divided into 3 subtypes, 2 of which concern us here. 1) The peat mound subtype is characterized by occasional large (up to 12 ft tall) mounds of peat 7 to 10 ft thick and frozen at shallow depths. 2) The wet tundra subtype (= the wet-tundra sedge-lichen type of Palmer and Rouse (1945)) is vegetated primarily by *Carex aquatilis* and *Eriophorum angustifolium*.

Salix spp., Sphagnum spp., moss, Empetrum nigrum, and Eriophorum scheuchzeri are also important. In general the soil of the wet tundra type is peat, 12-18 inches thick with a pH of 5.2-5.4 and underlain by a brownish-gray clay soil or a gley. The permafrost table in midsummer is usually about 16 inches below the surface.

Fay and Cade, 1959

Wet tundra on St. Lawrence Island is vegetated principally with Carex and Sphagnum and occasionally with dwarf shrubs and Caltha palustris. Standing water is often present, and even where it is absent the substrate is so wet that footprints immediately begin to fill with water.

Klein, 1958

Bog meadows are common in some sections of the flats, in broad valleys, and low mountain passes on St. Matthew Island where level ground is poorly drained. Dominant are Eriophorum angustifolium, E. russeolum, Carex stans, and C. bipartita. The intervening areas between the sedges are occupied by Sphagnum, other mosses, a few lichens, and several forbs.

Palmer and Rouse, 1945

A wet-tundra-sedge-lichen type is found extensively along the western Alaskan coast. In particular, one on Nunivak Island was examined. The soil is deep, spongy, and peatlike and saturated with moisture throughout the growing season. The vegetation is dominated by sedges, with lichens present in smaller quantities; Sphagnum and prostrate willows, dwarf

birch, and ericaceous shrubs are also present.

Rausch and Rausch, 1968

In wet meadows and along margins of ponds on St. Matthew Island, dense stands of Eriophorum angustifolium, Carex aquatilis, and C. lachenalii develop. Peat mounds in such areas are vegetated with mosses (including Sphagnum) and a few vascular plants. Moderately wet areas, sometimes at higher elevations, support a variety of plants including Sphagnum and other mosses and a number of grasses and forbs (p. 70).

Young, 1971

Bog soils constitute the substrate for half of St. Lawrence Island, and wet tundra vegetation occurs on these peaty substrates. Carex aquatilis is the most abundant species of the wet tundra and may form nearly pure stands. In slightly better drained areas Eriophorum angustifolium becomes dominant with Dupontia fisheri often being of major importance. Wet tundra is usually dotted with Sphagnum hummocks, frost boils, and raised polygons. Prostrate willows and a number of forbs grow on the hummocks.

Riparian gravel bar and cutbank

Bos, 1967

The riparian grass-browse type occurs in areas that are periodically flooded along the borders of streams and rivers and is best developed

where the stream channels are braided. Calamagrostis canadensis is dominant; Salix pulchra, S. alaxensis, S. reticulata, moss, Festuca altaica, and Sanguisorba sitchensis are also important. Salix pulchra is the most abundant willow, especially east of Nash Harbor. There are no shrub willows on the western tip of the island.

Palmer and Rouse, 1945

A grass-browse type occurs along shallow gulches and along stream courses and does not extend far to either side. The area examined was on Nunivak Island. The soil is fine, deep loam, rich in humus, and wet or saturated during most of the growing season. The vegetation is predominantly willows and grasses.

Young, 1971

Some of the large rivers have developed gravel bars of some size. Where they are frequently flooded a community consisting mainly of Salix pulchra and Epilobium latifolium occurs. At a slightly higher level Wilhelmsia physodes, Parnassia kotzebuei, and Silene acaulis also occur, these being rare in other habitats.

Strand and supratidal meadow

Bos, 1967

On Nunivak Island the beach grass-forb type occurs on coastal sand dunes and strand areas. Prevailing winds and ocean currents have favored

dune development on the southern and southwestern coasts. Elymus mollis is the dominant species; other species include Lathyrus maritimus, Festuca rubra, Calamagrostis lapponica, Achillea borealis, Artemisia arctica, Cnidium ajanense, Poa spp., and Conioselinum benthami.

The first plants to become established on the dunes are Arenaria peploides, Elymus mollis, Lathyrus maritimus, and Senecio pseudo-arnica.

On the south side of the island the sand dunes are moving seaward under the influence of prevailing northwest winds. As the dunes migrate, hollows formed by the wind fill with water and are colonized by Juncus balticus. As these sites become increasingly stabilized Carex spp. replace the Juncus.

Fay and Cade, 1959

Sandy and gravelly beaches, mud flats, gravel bars, and sandspits occur on St. Lawrence Island. Sea cliffs are common, of which the most characteristic plant is Sedum rosea, growing mostly on the upper levels.

Klein, 1958

Almost pure stands of Elymus mollis occur immediately behind the gravel beaches on the old raised beaches. The Elymus stabilizes the sand and gravel of these old beaches, but washouts from recent storms are evident. Scattered throughout the Elymus are Angelica lucida, Lathyrus maritimus, Cochlearia officinalis, Senecio pseudo-arnica, and Calamagrostis deschampsioides

In crevices on cliff faces fertilized by droppings from sea birds

Cochlearia officinalis, Arenaria peploides, Claytonia acutifolia, and a few grasses grow luxuriantly.

Palmer and Rouse, 1945

The sand-dune type on Nunivak Island has a deep soil composed of fine sand with very little humus. A small amount of wind-borne deposition is still taking place. The soil is well drained, but comparatively heavy precipitation during the summer furnishes ample moisture for abundant plant growth. The vegetation is dominated by Elymus mollis and Arctagrostis latifolia with smaller amounts of Poa arctica and Festuca rubra. Epilobium latifolium, Lathyrus maritimus, and other forbs are also present.

At Cape Etolin on Nunivak Island the beach-transition type occurs on fine, deep, well-drained, wind-blown sand with very little humus. The vegetation is composed of:

Elymus mollis
Epilobium latifolium
Artemisia arctica
Achillea borealis
Coelopleurum gmelini
Empetrum nigrum
Stereocaulon tomentosum
Polytrichun spp.
Bryum spp.

Rausch and Rausch, 1968

Stabilized beach ridges characteristically support dense stands of Elymus arenarius in association with Lathyrus maritimus, Senecio pseudo-arnica, and frequently Poa eminens. Angelica lucida is present locally.

Saline or brackish marsh

Bos, 1967

The tidal wetland subtype (of the wet tundra type) occurs in areas subject to flooding by sea water, especially during fall storms. Some small tidal wetland areas are present in the small bays on the north side of the island, but they reach their best development behind the sand dunes of the south side. This type intergrades with fresh water marsh (typical wet tundra) with increasing distance from the ocean. Important species are Carex subspathacea, C. glareosa, Elymus mollis, Stellaria humifusa, Poa eminens, Salix ovalifolia, and Potentilla pacifica.

Intertidal zone

McRoy, 1968

Beds of Zostera marina occur at the mouths of many rivers on Nunivak Island.

Vegetation maps

A vegetation map of Nunivak Island is found in Bos (1967, p. 36, figure 2).

BERING SEA MAINLAND

About half of this region consists of lowlands, primarily the Yukon-Kuskokwim coastal lowland and the Nushagak-Bristol Bay lowland (Wahrhaftig, 1965). The remainder consists of headlands, rolling uplands, and low rounded mountains, though some rugged, steep-sided mountains with sharp summits are found northwest of Dillingham (Wahrhaftig, 1965). A few major rivers such as the Yukon, Kuskokwim, and Nushagak enter the sea in this region. The Yukon River ends in a large delta with several major distributaries. The Kuskokwim and Nushagak rivers end in large estuaries that appear to be drowned river mouths (Wahrhaftig, 1965). Most other rivers are relatively small and short. Countless thaw and oxbow lakes are found on the Yukon-Kuskokwim coastal lowland and abundant thaw, oxbow, and kettle lakes occur on the Nushagak-Bristol Bay lowland. A number of large moraine-dammed lakes in ice-scoured valleys are found in the glaciated mountains bordering the Nushagak-Bristol Bay lowland. Scattered thaw and oxbow lakes are present in other valleys and low-lying areas (Wahrhaftig, 1965).

This region has only a few small cirque glaciers in the mountains northwest of Dillingham at the present time. A larger area has undergone glaciation in the past, but most of the region has never been glaciated (Wahrhaftig, 1965). Most of the mainland is generally underlain by continuous permafrost except for the area south and east of the Kuskokwim valley, where permafrost occurs only sporadically (Viereck and Little, 1975). Tidal fluctuation is relatively low, except for the

Bristol Bay area; extreme tides range from 2 to 8.5 ft above mean sea level to 0.5 to 2 ft below, only one high and one low tide occurring per day during part or all of each month. Tidal fluctuation is much stronger in the Bristol Bay area, extreme high and low tides reaching 23 ft above and 3.7 ft below mean sea level at Clark Point. In the Bristol Bay area the normal tidal pattern of two tides per day (two high and two low tides) occurs thoughout the month (Johnson and Hartman, 1969). In addition to normal tides, this region is subject to storm tides caused by prolonged strong westerly winds. These winds, blowing over the shallowly submerged Bering Platform, can cause a rise in the seas of several feet (Johnson and Hartman, 1969), and driftwood has been found along creeks ten miles inland near Pastolik (Porsild, 1939). The coast of the entire region is covered by sea ice in the wintertime, though shifting of ice off-shore provides a small amount of open water near the coast (Johnson and Hartman, 1969).

The climate is classified as transitional, indicating a colder average temperature, a greater diurnal and annual temperature variation, and less precipitation than areas with truly maritime climates. The average annual temperature ranges from 35° F in the south to 22° F in the north. Summers are cool and moist because of the proximity of the sea. The presence of sea ice in the winter, however, gives the climate a continental aspect, and cold, relatively dry conditions prevail during this period; intense storms are frequent (Johnson and Hartman, 1969; Hopkins and Sigafoos, 1951). Mean annual precipitation varies from 80 inches in the mountains northwest of Dillingham to about 20 inches in

most of the rest of the region (Viereck and Little, 1975).

The vegetation of this region is primarily tundra with closed forests of spruce (Picea glauca and/or P. mariana) and birch (Betula papyrifera) in the southeastern part of Seward Peninsula, north and east of Dillingham, and along the Yukon River at the eastern edge of this region (Viereck and Little, 1975). Balsam poplar (Populus balsamifera) and tall willows are found along stream courses. A great deal of variability is found in the tundra vegetation, which varies from low scattered plants on dry wind-swept ridges to lush growths of sedges and grasses in especially favorable sites on sheltered lowlands.

References to Wetlands of the Bering Sea Mainland

Brandt, Herbert. 1943. Alaska Bird Trails. The Bird Research Foundation, Cleveland, Ohio. 464 p.

Burns, John J. 1964. The ecology, economics, and management of mink in the Yukon-Kuskokwim delta, Alaska. Univ. of Alaska M.S. thesis. 114 p.

Hanson, Herbert C. 1953. Vegetation types in northwestern Alaska and comparisons with communities in other arctic regions. Ecology 34: 111-140.

Hopkins, D. M. and R. S. Sigafoos. 1951. Frost action and vegetation patterns on Seward Peninsula, Alaska. U.S. Geol. Surv. Bull. 974-C. p. 51-100.

Hultén, Eric. 1962. Flora and vegetation of Scammon Bay, Bering Sea coast, Alaska. Svensk. Bot. Tidsk. 56:36-54.

Hultén, Eric. 1966. Contributions to the knowledge of flora and vegetation of the southwestern Alaskan mainland. Svensk. Bot. Tidsk. 60:175-189.

McRoy, C. Peter. 1968. The distribution and biogeography of Zostera marina (eelgrass) in Alaska. Pacific Sci. 22:507-513.

Palmer, Lawrence J. and Charles H. Rouse. 1945. Study of the Alaska tundra with reference to its reactions to reindeer and other grazing. USDI Fish and Wildlife Service, Research Report 10. 48 p.

Pegau, Robert E. 1968. Reindeer range appraisal in Alaska. University of Alaska M.S. thesis. 130 p.

Porsild, A. E. 1939. Contributions to the flora of Alaska. Rhodora 41:141-301.

Pond and lake

Brandt, 1943

Inland of the beach at Hooper Bay there are irregular parallel ridges of white sand. Between these are series of small shallow ponds of very clear fresh water with white sandy bottoms.

Hanson, 1953

In shallow parts of fresh water ponds and in the wet soil of pond margins and stream banks are _Ranunculus pallasii_, _R. aquatilis_, _Hippuris vulgaris_, _Potamogeton_ spp., _Callitriche_ sp., _Equisetum fluviatile_, and _Carex aquatilis_. In brackish water _C. subspathacea_ and _Hippuris_ sp. also occur.

Hultén, 1966

In southwestern Alaska up to 50% of some areas are covered by shallow lakes which practically lack flowering plants or which have a few plants of _Sparganium hyperboreum_ or _Potamogeton perfoliatus_ and sometimes also _Hippuris vulgaris_ and _Menyanthes trifoliata_. Occasionally _Nuphar polysepalum_ occurs.

Porsild, 1939

At Pastolik ponds and lakes are sparsely vegetated with _Sparganium hyperboreum_, _Potentilla palustris_, _Hippuris vulgaris_, and _Ranunculus pallasii_ (other species listed on p. 159). At Unalakleet _Potamogeton_

gramineus and *P. tenuifolius* were found in some small lowland ponds.

Fresh water marsh

Hultén, 1966

Pure stands of *Arctophila fulva* grow along the margins of the Eek River.

Palmer and Rouse, 1945

The wet-tundra sedge type is common on lowlands. The soil is fine and deep with a high humus content. These areas are usually flooded during the spring, and the soil remains saturated throughout the summer. The vegetation is dominated by *Carex*.

The coast-tundra sedge-browse type is found on practically all the lower ground near the coast, occupying the valley floors and poorly drained flats adjacent to the beach. The area examined was on a gentle northeast slope about .5 mi from the beach near Egavik. The soil is a fine-textured loam with abundant humus. The vegetation is composed largely of *Eriophorum* and *Carex* with dwarf birch and ericaceous shrubs.

Pegau, 1968

The wet subtype of *Eriophorum*-*Carex*-dwarf-shrub meadow occurs along ponds and streams in which *Carex aquatilis*, *C. kelloggii*, *Eriophorum angustifolium*, and *E. scheuchzeri* dominate.

atland

Burns, 1964

There are extensive low-lying wet areas between Bethel and Baird let, and near the mouth of the Yukon River. During spring and early mmer most of this area is covered with water which drains off as summer ogresses. Common plants are:

Menyanthes trifoliata	Polemonium acutiforum
Caltha palustris	Carex aquatilis
Petasites frigidus	Rumex sibiricus
Draba alpina	Salix pulchra

Hanson, 1953

The sedge-Sphagnum moss bog type is characterized by an abundant owth of Sphagnum several inches thick. Sedges, cottongrass, dwarf ubs, especially heaths, and a few grasses and forbs grow to a height about 15 inches. Black spruce is found in the eastern part of the region.

Fresh water sedge marshes [included here because of their peaty sub-ate] are dominated by Carex aquatilis and C. rotundata. Some mosses icluding Sphagnum) and some shrubby species (such as Salix pulchra) fairly prominent. The surface hummocks are 6 to 8 inches high. The strate is a dark red to brown fibrous peat 12 inches thick with a pH 5.6 to 5.8 overlying frozen gravel and rock.

Hopkins and Sigafoos, 1951

A sedge sod occurs on poorly drained sites where water lies at the

surface and where lateral flow is restricted. Such places occur on broad summits, gentle slopes, in drainage courses, and around the margins of many ponds. The sod is an interwoven mass, 6 to 10 inches thick, of rhizomes of *Carex aquatilis* firmly rooted in a thick layer of fibrous peat. The peat is an accumulation of dead parts of *Carex*, *Eriophorum*, and mosses. The peat is from 1 to 10 ft thick, but is interrupted locally by areas of bare soil. Primary species are *Eriophorum angustifolium* and *Carex aquatilis*.

Pegau, 1968

A sedge-*Sphagnum* moss type is common within or near the spruce forest. The *Sphagnum* mat is several inches thick, and sedges and ericaceous shrubs occur sparingly throughout.

Porsild, 1939

Carex bogs on the Yukon delta are formed by stands of *Carex lyngbyaei*, *Eriophorum* spp., and *Sphagnum*. "Bog-filled frost cleavages" (polygon troughs) are vegetated at Pastolik by *Eriophorum russeolum* and *E. angustifolium* with several species of *Carex*. Near the edge of ponds are *Caltha natans*, *Epilobium palustre*, *Cicuta mackenzieana*, *Coelopleurum gmelini*, *Carex aquatilis*, and *C. rostrata*.

Riparian gravel bar and cutbank

Burns, 1964

Between Bethel and Baird Inlet and on the Yukon delta, land which is slightly higher and better drained than the wet tundra surface supports willows, usually along streams where a high bank affords protection from abrasion by wind-driven snow. In areas close to the Kuskokwim River *Alnus crispa* grows with the willows.

Hanson, 1953

The feltleaf willow type occupies the well-drained banks of streams. The willows usually grow from 5 to 15 ft high. The dominant species is *Salix alaxensis*; associated species are balsam poplar, alder, *Potentilla fruticosa*, grasses, sedges, and mosses.

The greenleaf willow type often occurs adjacent to the feltleaf willow type in less well-drained areas farther from the rivers. Dominant species are *Salix richardsonii*, *S. pulchra*, and/or *S. fuscescens*. The height of these willows varies from 4 to 8 ft.

Hultén, 1966

Gravel bars at uppermost Eek River are occupied by:

Equisetum arvense	*Senecio congestus*
Agrostis scabra	*Stellaria crassifolia*
Solidago multiradiata	*Deschampsia beringensis*
Epilobium latifolium	*Artemisia tilesii*
	others (p. 179)

Hultén, 1966

Riparian Salix thickets generally include Salix alaxensis, S. arbusculoides, Calamagrostis canadensis, and several forbs (p. 178-179).

Hultén, 1962

Scattered Salix pulchra and abundant Calamagrostis canadensis grow along creeks at Scammon Bay, along with other species (p. 40).

Strand and supratidal meadow

Brandt, 1943

At Hooper Bay there are irregular parallel ridges of white sand, 30 ft or less in height, sparsely covered with tufted clumps of long grass.

Hultén, 1962

Slightly elevated sites at Scammon Bay lack Eriophorum, Empetrum, and Vaccinium but support:

Elymus arenarius	Rumex arcticus
Ligusticum hultenii	Salix ovalifolia
Potentilla egedii	Primula borealis
Stellaria humifusa	others, p. 39

Palmer and Rouse, 1945

At Pastolik the beach-transition type is dominated by Arctagrostis,

Poa, and Agrostis and occurs on a soil of smooth, fine gravel and sand with a fair amount of humus. Soil moisture is plentiful throughout the growing season.

Pegau, 1968

Elymus mollis dominates a narrow strip along the beach where the soil is sand; other species are Angelica lucida, Lathyrus japonica, Arenaria peploides, and Equisetum spp.

Porsild, 1939

At St. Michaels, in low wet meadows between the hills and the lagoon and on low, stable dunes, a varied and interesting littoral flora is composed of Poa eminens, Carex gmelini, Atriplex gmelini, Koenigia islandica, Montia lamprosperma, and others (p. 161).

Saline or brackish marsh

Brandt, 1943

Behind the coastal dunes and along the sluggish streams at Hooper Bay are vast grassy flats. These are usually just above high tide level, but, in the autumn, they can be submerged by storm tides. Sluggish sloughs with an ordinary tidal rise and fall of about 4 ft a day meander through these flats.

Hanson, 1953

Saline marshes occur extensively in estuaries and borders of lagoons. Species characteristic of these sites are Carex cryptocarpa and C. subspathacea. Early invaders on mud flats are Puccinellia borealis, Stellaria humifusa, and Potentilla pacifica.

Hultén, 1962

Near Scammon Bay is a very low tundra plain with innumerable ponds and lakes; the lower parts are soaked by salt water at high tide. The tide is fairly high here and only the higher parts escape inundation. The salt water goes far inland, apparently for many miles, probably nearly to the base of the Kusilvak Mountains. In the lakes are Hippuris tetraphylla and floating Sphagnum. Shores of lakes are occupied by:

Carex lyngbyaei	Angelica lucida
C. rariflora	Eriophorum russeolum
Betula nana	Petasites frigidus
Spiraea beauverdiana	

Intertidal zone

Hultén, 1962

The banks of the Kun River and its tributaries at Scammon Bay are covered at ebbtide by a fine mud and mudflats extend for several miles.

McRoy, 1968

Beds of Zostera marina are common in protected bays, lagoons, and inlets in the Norton Sound-Seward Peninsula area. This species is rare or lacking farther south in the Bering Sea mainland region but has been reported from Nanvak and Chagvan bays, near Cape Newenham.

Vegetation maps

Palmer and Rouse (1945) provide a vegetation map of the Unalakleet-Egavik Reindeer Allotment (Figure 9, opposite p. 44).

CHUKCHI SEA

In this region extensive lowlands are found on the northwestern spur of Seward Peninsula, the Selawik Basin, the lower parts of the Kobuk and Noatak rivers, and the region extending eastward from the coast between Noatak and Icy Cape. The remainder consists of rolling uplands and low rounded mountains with the exception of some sharp rugged peaks in the DeLong, Baird, and Schwatka mountains (Wahrhaftig, 1965). Only a very few small cirque glaciers exist in the area at the present time, though most of the valleys of the Brooks Range were glaciated during the Pleistocene (Wahrhaftig, 1965). Continuous permafrost underlies the whole region (Viereck and Little, 1975). Ice wedges are well developed on most of the lowlands and create a microtopographic pattern of high- or low-center polygons.

Major rivers include the Kobuk and the Noatak, both of which have built sizable deltas. Thaw lakes abound on the lowlands of this region and oxbow lakes are common on large floodplains. A few moraine-dammed lakes are found in glaciated valleys of the Brooks Range and the mountains of the Seward Peninsula. Several sizable lakes occur in bedrock basins on the Seward Peninsula, most notably Imuruk Lake (Wahrhaftig, 1965). Tidal fluctuations in this region are small, extreme high and low tides of approximately 3.4 ft above and 0.8 ft below mean sea level occurring at Kiwalik. In addition to normal tides this region is subject to storm tides caused by strong westerly winds during which the sea may rise as much as 3 ft (Johnson and Hartman, 1969). The entire coast is bound

by ice in the wintertime, though shifting of ice off-shore provides small amounts of open water. The sea ice persists until late spring or early summer, breaking up on the average in early May at Kotzebue and by mid-June at Point Hope. The sea freezes in October or November (Johnson and Hartman, 1965).

This region has an arctic climate characterized by cool summers and cold winters. The average annual temperature ranges from 22° F in the south to 12° F in the north. Average annual precipitation varies from 20 inches in the south to less than 10 inches in the north (Viereck and Little, 1975).

The vegetation is primarily tundra and is influenced strongly by frost-related microtopographic features such as polygon troughs and centers, hummocks, and frost scars. Open forests of white spruce (*Picea glauca*) occur in parts of the lowland near Selawik, the Kobuk Valley, and the lowermost portion of the Noatak Valley. Black spruce (*Picea mariana*) and paper birch (*Betula papyrifera*) grow in the Kobuk Valley, and balsam poplar (*Populus balsamifera*) and tall willows grow along floodplains the entire length of both the Kobuk and Noatak valleys (Viereck and Little, 1975). Tall willows are found along streams throughout the area, though in the northern part of the region they are not really very tall and are not found within a few miles of the coast.

References to Chukchi Sea Wetlands

Childs, Henry E., Jr. 1969. Birds and mammals of the Pitmegea River region, Cape Sabine, northwestern Alaska. Biol. Pap. Univ. Alaska No. 10. 76 p.

Dean, Frederick C. and David L. Chesemore. 1974. Studies of birds and mammals in the Baird and Schwatka Mountains, Alaska. Biol. Pap. Univ. Alaska No. 15. 80 p.

Hanson, Herbert C. 1950. Vegetation and soil profiles in some solifluction and mound areas in Alaska. Ecology 31:606-630.

Hanson, Herbert C. 1951. Characteristics of some grassland, marsh, and other plant communities in western Alaska. Ecol. Monogr. 21:317-378.

Hanson, Herbert C. 1953. Vegetation types in northwestern Alaska and comparisons with communities in other arctic regions. Ecology 34:111-140.

Johnson, A. W., L. A. Viereck, R. E. Johnson, and H. Melchior. 1966. Vegetation and flora of the Cape Thompson-Ogotoruk Creek area, Alaska, p. 277-354. _In_ Wilimovsky, N. J. and J. N. Wolfe, eds., Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Commission, Div. Tech. Inf., PNE-481.

McRoy, C. Peter. 1968. The distribution and biogeography of _Zostera marina_ (eelgrass) in Alaska. Pacific Sci. 22:507-513.

Melchior, Herbert R. 1973. Biological survey of the Kobuk Sand Dunes. Chukchi-Imuruk Biological Survey Interior Report. Cooperative Park Studies Unit, Univ. Alaska. 14 p.

Melchior, Herbert R. and Charles H. Racine. 1974. Kobuk National Monument biological survey, second interim report. Cooperative Park Studies Unit, Univ. Alaska. 14 p.

Racine, Charles H. 1974. Vegetation of the Chukchi-Imuruk area (manuscript). Chukchi-Imuruk Biological Survey, Cooperative Park Studies Unit, Univ. Alaska. No pagination.

Shacklette, Hansford T. 1965b. Bryophytes associated with mineral deposits and solutions in Alaska. U.S. Geol. Surv. Bull. 1198-C. 17 p.

Thomas, John H. 1951. A collection of plants from Point Lay, Alaska. Contr. Dudley Herb. 4:53-56.

Ugolini, Fiorenzo C. and James Walters. 1974. Pedological survey of the Noatak River Basin, p. 86-156. _In_ Young, S. B., ed., The Environment of the Noatak River Basin, Alaska. Center for Northern Studies, Wolcott, Vermont.

Young, Steven B. 1974. Vegetation of the Noatak River Valley, Alaska, p. 58-84. In Young, S. B., ed., The Environment of the Noatak River Basin, Alaska. Center for Northern Studies, Wolcott, Vermont.

Pond and lake

Childs, 1969

At Cape Sabine *Arctophila fulva* grows with some aquatic mosses in water deeper than 6 inches usually on the edges of ponds.

Johnson *et al.*, 1966

The small bodies of fresh water in the Ogotoruk Valley are surprisingly low in aquatic species. Except for emergent species growing along the edges of ponds, these habitats have few vascular plants; occasionally *Ranunculus hyperboreus*, *R. gmelinii*, *R. aquatilis*, *Sparganium hyperboreum*, and, rarely, *Potamogeton pectinatus* and *P. filiformis* grow in ponds. Emergents of the pond margins are *Arctophila fulva*, *Hippuris vulgaris*, *Ranunculus pallasii*, *Potentilla palustris*, *Carex aquatilis*, and occasionally *Caltha palustris*.

Racine, 1974

In the Chukchi-Imuruk area *Hippuris vulgaris* (*H. tetraphylla* in brackish water) forms stands in shallow ponds and along lake margins in the Chukchi-Imuruk area. Associates are *Potentilla palustris*, *Ranunculus pallasii*, and *Caltha palustris*.

Young, 1974

In general, aquatic vegetation is confined to small lakes, thaw ponds, and slow-moving streams. Aquatic vegetation varies greatly from one pond to another and from one portion of a pond or lake to another. The most varied aquatic vegetation is found in ponds that shelve slowly from sandy

or muddy shores. The actively eroding shores of thaw ponds lack aquatic vegetation. In a typical pond with well-developed aquatic vegetation the shore slopes gently from areas of wet tundra, shrub-tussock tundra, or occasionally willow thickets. The vegetation is arranged in zones depending mainly on water depth but also on the size of the lake, mainly through the relationship of size and wave action.

In water over 1 m deep Myriophyllum spicatum, Potamogeton spp., and occasionally Lemna trisulca are found. In shallower water Potamogeton filiformis, P. pectinatus, Zannichellia palustris, and Sparganium hyperboreum are important. In still shallower water Equisetum fluviatile, E. palustre, Arctophila fulva, Ranunculus pallasii, Caltha palustris, Potentilla palustris, Hippuris vulgaris, and Menyanthes trifoliata are found. These vary in importance from pond to pond, and it would be unusual to find them all in the same area.

In ponds surrounded by tundra vegetation, the plants of the shoreline are wet tundra species with Eriophorum angustifolium, E. brachyantherum, and Carex aquatilis being most important. Ponds with muddy shores have the most complex shoreline vegetation. Exposed mud flats usually support the majority of the species present on the tundra-vegetated shorelines with Hippuris vulgaris often being dominant. Other species are Calamagrostis sp., Juncus castaneus, J. arcticus, Koenigia islandica, Rumex arcticus, Epilobium palustre, and Senecio congestus.

Fresh water marsh

Childs, 1969

Tussock wet meadow occurs on upland tundra soils. The dominant species is Eriophorum vaginatum and other important species are Carex bigelowii, Ledum palustre, Vaccinium vitis-idaea, mosses, and lichens. This community is also sometimes found on peat.

Sedge-willow wet tundra is wetter than tussock wet meadow and occurs in topographically lower positions on meadow tundra soils and occasionally on pseudo-tussocks and peat stringers. Characteristic species are Carex aquatilis, Salix pulchra, Eriophorum angustifolium, Valeriana capitata, and Polemonium acutiflorum. This community is widely distributed and well developed in the study area.

Arctophila marsh consisting of pure stands of Arctophila fulva occurs with some aquatic mosses where standing water more than 6 inches deep prevails, primarily at pond edges and in stream beds.

Dean and Chesemore, 1974

The sedge-grass marsh type is occasionally found on mineral soils (as well as bog or half-bog soils). The most extensive marshes on mineral soils are dominated by one or two species of Carex and Calamagrostis. A few 'orbs such as Potentilla palustris are also common.

Johnson et al., 1966

Two subtypes of the Eriophorum-Carex wet meadow can be considered here. They both occur on humic or low-humic gley tundra soils and are much alike,

ept that one of them is characterized by low ridges running at right les to the gentle slopes. As a consequence of the relatively dry habitats orded by the ridges, this subtype has a more varied flora. Both types are dominated by Carex aquatilis, Eriophorum angustifolium, E. seolum, and E. scheuchzeri. Frost scars are abundant in both types.

Eriophorum tussock vegetation may also warrant inclusion here. This etation type occurs at least in part in areas of low relief in wet, cold, -humic gley tundra soils of the Ogotoruk Creek drainage. Eriophorum sock vegetation may be roughly divided into two subtypes on the basis presence or absence of ice-wedge polygons; the tussock stands which lack -wedge polygons have considerably more frost scars than those which have polygons. In general the polygonal stands occupy wetter sites than the polygonal stands. Depressions with Carex aquatilis, Eriophorum angustiium, and Sphagnum spp. overlie the ice wedges.

The Eriophorum-Carex solifluction slopes type is similar to the wet dow but occurs on steep slopes below persistent snowbanks on deep, very , cold mineral soils. Permafrost is rarely further than 1 or 2 ft n the surface. The vegetation consists of a sedge mat of Eriophorum ıstifolium, Carex aquatilis, and Carex bigelowii. The most conspicuous ture of these cold wet slopes is the series of large solifluction lobes :h are 0.5 to 1.0 m high at the down-slope edge, 6 to 10 m long, and) 4 m wide.

Melchior, 1973

In the vicinity of the Great Kobuk Dunes, wet banks along braided

streams support *Carex aquatilis*, *C. membranacea*, and mosses.

Melchior and Racine, 1974

In the Kobuk River Valley marsh vegetation represents the filling-in of old lake basins which in turn have developed from old river meanders. In these sites, zones dominated by *Carex rostrata*, *Equisetum fluviatile*, and *Hippuris vulgaris* are found.

Racine, 1974

A *Calamagrostis* meadow occurs in wet drainageways, usually bordered by willow shrub thicket. *Calamagrostis canadensis* is dominant and sometimes forms very large tussocks up to 1 m in diameter and 1 m high. These meadows also develop in recently drained lakes.

Ugolini and Walters, 1974

Wet swales are vegetated by *Salix* spp. on slopes of meadow tundra soils. Standing water is present in places and the depth of the frost table is only 31 cm.

Young, 1974

Tussock and shrub-tussock tundra is the most extensive and characteristic vegetation throughout most of the Noatak Valley at elevations of 2000 to 3000 ft. Most of the gently rolling drift-covered portions of the study area are covered with this vegetation. In its simplest form it occurs as almost pure stands of *Eriophorum vaginatum*. In its purest form, tussock

tundra seems to be correlated with intense disturbance by frost action; frost boils are closely and regularly distributed throughout tussock tundra areas.

In many areas tussock tundra is being invaded to some extent by Sphagnum spp. and a characteristic array of shrubby plants. In these areas the tussocks are less well developed, and, where shrub-tussock tundra adjoins wet tundra, the tussocks may be almost completely overgrown with Sphagnum.

Small areas of wet tundra occur in alpine valleys and seepage areas at elevations of 3000 to 5000 ft in the middle and upper Noatak Valley. These are similar in aspect and species composition to wet tundra near sea level in coastal areas such as Point Barrow and St. Lawrence Island.

Peatland

Childs, 1969

Sedge-marsh vegetation usually develops on bog or half-bog soils, but is occasionally found on wet alluvium. Standing water up to 6 inches deep is usually present during the growing season. Dominant species are Carex aquatilis and Eriophorum angustifolium. Indicator species are Potentilla palustris, Caltha palustris, and Sphagnum spp.

Dean and Chesemore, 1974

Sedge-grass marsh is dominated by one or two species of Carex and Calamagrostis. Potentilla palustris is also common. This type occurs as relatively narrow borders along sloughs, streams, and lakes or fills shallow ponds which are frequently of oxbow origin. It occurs on both mineral and peaty soils.

Hanson, 1950

A hummocky sedge-heath occurs near Kotzebue on land that is fairly level to gently rolling. Ridges and hummocks from 2 to 15 inches high form along irregular lines. Between the ridges are depressions one to several feet wide where the vegetation is principally sedges and a few other species (p. 623). This area is underlain by 10 to 14 inches of peat, most of it saturated with water. Permafrost was found at 15 inches, and standing water occurs in some depressions.

Hanson, 1951

Carex aquatilis-*C. rotundata* stands in the Kotzebue lowland occur in basin-like areas that at one time had probably been brackish ponds subject to overflow from storm waters. As elevation increased through siltation and peat accumulation, these became fresh water pools or brackish marsh and finally fresh water marsh. Other prominent species are *Eriophorum angustifolium* and *E. chamissonis*. The soil is a 16-inch layer of peat underlain by rather impervious silt. The water table lies at 6 inches beneath the surface and the permafrost table is 22 inches deep.

Hanson, 1953

Cloudberry-dwarf shrub marsh is common on the lowlands north of Imuruk Basin. The stand investigated was on moist peat strips running parallel to the gentle south-facing slope and alternating with fresh water sedge-marsh. Most common plants include *Vaccinium vitis-idaea*, *Betula nana*, *Empetrum nigrum*, *Rubus chamaemorus*, *Ledum decumbens*, and *Vaccinium uliginosum*.

Johnson _et_ _al_., 1966

Eriophorum-Carex wet meadow vegetation occupies the lowest, wettest, nonaquatic sites in Ogotoruk Valley. It is abundant but not as extensive as the _Eriophorum_ tussock vegetation. It is dominated by _Carex aquatilis_ and _Eriophorum angustifolium_. It occurs mostly in areas bordering lakes and streams, on shallow drainage slopes, and on extensive low flats along Ogotoruk Creek. This type grows up to the edge of open water on one extreme and intergrades with _Eriophorum_ tussock tundra on the other. The wettest stands, on half-bog soils of low-center polygons, are relatively poor in species, except for those named above which grow abundantly. In many places an almost continuous mat of _Sphagnum imbricatum_ and _S. balticum_ covers the ground in spongy hummocks.

Melchior and Racine, 1974

On the Kobuk River, bog vegetation represents the filling-in of old lake basins. _Menyanthes trifoliata_, _Drosera rotundifolia_, _Chamaedaphne calyculata_, and _Potentilla palustris_ are common species.

Racine, 1974

Three types of meadow vegetation on the Seward Peninsula can be included here: 1) _Eriophorum angustifolium_ wet meadows are found mainly on the flats bordering Lava Lake; 2) _Eriophorum angustifolium-Carex aquatilis_ wet meadows occur locally along the coast; 3) _Carex aquatilis_ wet meadows are developed locally along the coast and on flat summits and lower slopes. _Eriophorum vaginatum_ and _E. russeolum_ are common associates, and peaty hummocks

or ridges are often scattered through all three types.

Ugolini and Walters, 1974; Young, 1974

Most of the areas in the Noatak Valley vegetated with wet tundra have half-bog soils. Permafrost occurs at shallow depths. Wet tundra is defined as tundra with standing water for most of the summer in normal years and in which tussocks are poorly developed or absent. It normally occurs in areas of low-center polygons and on slopes where a characteristic system of transverse peat ridges impede drainage. Dominant species are usually _Arctophila fulva_, _Carex aquatilis_, _Eriophorum brachyantherum_, _E. angustifolium_, and _E. chamissonis_, listed approximately in descending order of their tolerance for standing water. Other _Carex_ species are locally abundant. Low willows (primarily _Salix pulchra_, _S. fuscescens_, and _S. arctica_) as well as some forbs (such as _Saxifraga hirculus_, _Polygonum viviparum_, and _Pedicularis sudetica_) are often important on the peat ridges and edges of polygons.

Stream

Young, 1974

Small slow-moving streams usually have steep banks with little shoreline vegetation. Aquatics are usually not well represented but a few species, particularly _Sparganium hyperboreum_ and _Ranunculus pallasii_, are often abundant.

[Figures 10-13 show the vegetation along cross sections of the Noatak Valley.]

Riparian gravel bar and cutbank

Childs, 1969

Alluvial barrens of sand and gravel bars are characterized by *Artemisia* spp. and *Epilobium angustifolium*.

Shrubby riparian vegetation does not occur near the mouth of the Pitmegea River but about 5 miles inland shrubs are well developed with *Salix alaxensis* 2 to 6 ft tall and *S. glauca* and *S. richardsonii* 1 to 4 ft high as associates. An understory of *Equisetum* sp., *Arctagrostis latifolia*, or moss was usually present.

On the floodplain the lowland willow shrubs type is composed of *Salix glauca*, *S. richardsonii*, and *S. pulchra* generally growing less than 2.5 ft high. The understory includes alluvium-inhabiting perennials, marsh sedges, *Arctagrostis latifolia*, and *Equisetum* sp.

Dean and Chesemore, 1974

The tall shrub type consists of alder and/or willows and is commonly encountered as a band along water courses and lake shores. They vary from only a few feet in width to extensive stands up to half a mile or more wide. This type also occurs just above the forest on slopes.

Hanson, 1953

The feltleaf willow type, dominated by *Salix alaxensis*, is widespread on well-drained banks of streams with coarse gravel at a depth of about a foot. The willows range in height from 5 to 15 ft. Associated species include *Populus balsamifera*, alder, *Potentilla fruticosa*, grasses, sedges,

and mosses.

The greenleaf willow type is composed of Salix richardsonii, S. pulchra, and S. fuscescens and is found on stream bottoms adjacent to the feltleaf willow type, on steep banks, and in drainage ways on slopes. In poorly drained sites, sedges are more abundant; in drier sites, birch shrubs are associated with the willows.

Johnson et al., 1966

Perennial-herb communities on gravel bars are composed of Epilobium latifolium, Artemisia tilesii, A. arctica, Hedysarum alpinum, Lupinus arcticus, Elymus mollis, Arenaria macrocarpa, A. arctica, Festuca rubra, F. vivipara, Luzula confusa, and many other species. Willows begin to develop directly on bare alluvial gravels, the two most important species being Salix pulchra and S. alaxensis. Near the coast the latter is the most common; about five miles inland the two occur in almost even numbers; and about six miles upstream from the mouth S. pulchra reaches its maximum development, forming dense stands up to three meters tall. The invading willows gradually eliminate the perennial herbs; where the willows form continuous, dense stands the only plants that grow well are various mosses and lichens. Where Salix pulchra dominates the gravel bar communities the perennial herbs are limited to scattered Epilobium latifolium, Festuca altaica, Anemone richardsonii, Polemonium acutiflorum, Artemisia tilesii, and Arnica lessingii. In this area, however, about 80% of the soil surface is covered by the mosses Hylocomium spendens, Drepanocladus aduncus, Aulocomnium palustre, and Climacium dendroides.

Melchior, 1973

In the vicinity of the Great Kobuk Dunes the benches along braided streams such as Kavet Creek and Ahnewetut Creek support a mosaic of vegetation types. Low-growing patches of Salix spp. dominate some areas, but other areas lack shrubs altogether; in a few places Potentilla fruticosa is the prominent shrub. Moist sites support Dryas octopetala (?), Andromeda polifolia, Saxifraga oppositifolia, and Equisetum sp. Tall shrubs, mainly Alnus crispa and Salix spp., occur along the upper drainages of Ahnewetut Creek.

Racine, 1974

Willow-shrub thickets up to 6 m tall are fairly common throughout the Chukchi-Imuruk area, but are most extensive along outwash flats of the larger rivers and in protected drainageways where thawed ground is deep. The dominant species is usually Salix alaxensis with S. lanata as an associate. Close to the coast the willow thickets are about 2 m high and Salix brachycarpa spp. niphoclada is added to the understory.

Low to medium height willow-shrub thickets, 1 to 2 m tall, cover extensive areas along small drainageways. The large areal extent of these low shrub thickets is a distinctive feature of the vegetation in the Chukchi-Imuruk area. Salix planifolia spp. pulchra is dominant with S. glauca as an associate. Willows can cover about 50% to 90% of the ground within broad drainageways along slopes where they contrast sharply with tussock shrub tundra on both sides of the drainageway. The shrub

thicket may locally give way to wet meadow where there is excess water.

Thomas, 1951

The lower parts of the banks along the Kukpowruk River at Point Lay support *Chrysosplenium tetrandum*, *Equisetum arvense*, *Parnassia kotzebuei*, and *Poa arctica*. The upper portions support a scrubby growth of willows and dwarf birch which is usually 2 to 3 ft high.

Young, 1974

Many river banks and gravel bars support vegetation similar to that of muddy pond shores except that the larger, more fragile species such as *Senecio congestus* are absent. Pure stands of *Equisetum variegatum* or *Triglochin palustre* cover considerable areas below the high water mark. On drier banks and gravel bars *Epilobium latifolium* is the most important species, and fell-field species such as *Crepis nana* occur there also.

Gravel bars subject to frequent or prolonged flooding support only small, scattered willows contorted by water or ice action. In less exposed situations willows form dense thickets with a canopy from 1.5 to 5 m above the ground. The most important shrubby species are *Salix pulchra*, *S. glauca*, *S. alaxensis*, *S. lanata*, and *S. arbusculoides*. *Alnus crispa* occurs occasionally in these sites, usually near the edges of willow stands. Associated herbaceous species in the heavily flooded areas are *Epilobium latifolium* and *Castilleja caudata*. Particularly characteristic of the more stable willow thickets are *Anemone parviflora* and *A. richardsonii*.

Strand and supratidal meadow

Childs, 1969

Beach barrens along the coast are characterized by Elymus arenarius and Sagina intermedia.

Hanson, 1953

The first invaders of sandy shores are Mertensia maritima and Arenaria peploides. Along sandy and gravelly beaches above the reach of ordinary high tides and along some streams the beach rye type is found dominated by Elymus mollis with Lathyrus maritimus, Poa eminens, and a few other forbs. On the landward side of dunes in more stabilized soil, Festuca rubra, Poa sp., and a variety of forbs occur.

Johnson et al., 1966

The gravelly beaches found along the coast in the vicinity of Cape Thompson are not favorable for plant growth. Most of the common strand species prefer somewhat sandy soils, which are not abundant there. However, in a few scattered suitable habitats, Elymus mollis occurs associated with Senecio pseudo-arnica, Lathyrus japonicus, Honckenya peploides, Mertensia maritima, and Cochlearia officinalis. Two factors contributing to the paucity of strand plants are the plowing action of sea ice during the winter and spring and the alternating removal and deposition of tons of fine gravel by severe on-shore storms which sweep the entire beach area periodically during summer and fall. Consequently, strand plants are most often found on the lee side of barrier beaches, especially at the

mouths of small streams where finer textured materials are deposited.

Racine, 1974

Elymus arenarius is locally dominant in meadows on recently formed sand dunes along the Chukchi Sea coast as well as inland on gravel outwash flats and volcanic ash beaches. This type of vegetation covers a fairly extensive dune area extending from Cape Espenberg to Shishmaref. Common associates are *Festuca rubra*, *Lathyrus maritimus*, *Artemisia arcticus*, and *Honckenya peploides*. The *Elymus* is denser inland from the foredune area where *Myosotis alpestris*, *Carex gmelini*, and *Juncus arcticus* also occur in dune depressions.

Shacklette, 1965b

At Cape Krusenstern, the beach ridges nearest the water, receiving at least sea spray if not waves during storms, support a very limited bryoflora. *Tortula ruralis* is the most abundant bryophyte on these sites, although *Bryum argenteum* and *Ceratodon purpureus* are also present.

Thomas, 1951

Near the water on the barrier reef offshore from Point Lay, *Arenaria peploides*, *Cochlearia officinalis*, *Lathyrus maritimus*, *Mertensia maritima*, *Oxytropis nigrescens*, and *Puccinellia phryganodes* are found.

Saline or brackish marsh

Childs, 1969

Grasses of the genera *Puccinellia* and *Phippsia* dominate an estuary marsh near the mouth of the Pitmegea River.

Hanson, 1951

A long series of beach bars extends along the northwestern shore of Baldwin Peninsula from one headland northeastward toward another headland, almost enclosing a small bay. The spit is made up of broad low ridges and marsh. The vegetation of the marshy land varies considerably, from brackish sedge-marsh along inlets and ponds subject to overflow during storm periods, to fresh water sedge-marshes (treated here under bogs), sedge-heath hummocky mosaic-type communities, and gravelly low ridges between marshy areas. During storms the waves and wind raise the level of water along the beach facing Kotzebue Sound, and the water is backed up into the bay and ponds and on the lower marsh land, where it may remain for several days before slowly returning to usual levels.

A *Carex subspathacea* community forms a zone on the saturated borders and in shallow water of brackish pools and ponds subject to overflow by storm tides. *Carex glareosa*, *Potentilla pacifica*, *Elymus mollis*, and *Poa eminens* also occur in this zone. The soil is a dusky red to reddish-brown peat, 21 inches thick over silts, with no frozen ground within 36 inches. *Hippuris vulgaris* forms an open growth in deeper water.

Carex rariflora stands occur on slightly higher land that is exposed

to flooding by brackish water for shorter time intervals than the preceding stand. Low hummocks are scattered over the marsh. The general level is occupied chiefly by C. rariflora with scattered individuals of C. glareosa and a very few of C. subspathacea. The most common species on the hummocks are Salix ovalifolia, Festuca rubra, Empetrum nigrum, and Calamagrostis deschampsioides. The soil consists of 14 inches of muck and peat over gravel and silt.

Hanson, 1953

Saline marshes occur extensively on estuaries and borders of lagoons. Species characteristic of these sites are Carex cryptocarpa and C. subspathacea. Early invaders on mud flats are Puccinellia borealis, Stellaria humifusa, and Potentilla pacifica.

Johnson et al., 1966

A vegetation type of minor extent (less than 1% of the Ogotoruk Creek watershed area) occurs on wet alluvium near the mouth of Ogotoruk Creek. During on-shore storms this meadow is flooded by the Chukchi Sea, which deposits driftwood in large quantities. Most of the area is covered by an almost continuous sedge-grass mat, including Eriophorum angustifolium, Carex glareosa, Deschampsia caespitosa, Dupontia fisheri, Calamagrostis deschampsioides, Arctagrostis latifolia, Puccinellia phryganodes, P. langeana, and Arctophila fulva. The presence of such maritime species as Chrysanthemum arcticum, Potentilla egedii, and Matricaria ambigua reveals the influence of the sea on the composition of this vegetation type. The

ls are tundra humic gley types, and the permafrost levels are thought be deep (but not actually measured) because of periodic flooding of area by both the sea and Ogotoruk Creek.

Racine, 1974

Sandy and saline flats near the coast and along the estuaries at ring and at Cape Espenberg support extensive salt flat meadows. These e easily recognized as light green lawn-like areas with short prostrate ges and grasses including Puccinellia spp., Carex subspathacea, Carex enskii, and Carex lyngbyaei. In the salt flat meadows near Deering ng the Inmachuk River estuary, there are a number of associated forbs luding Saussurea nuda, Cochlearia officinalis, Potentilla egedii, and mula borealis with a few individuals of Elymus arenarius and Chrysanthemum ticum on higher sandy mounds.

Young, 1974

Coastal marshes occur in the vicinity of the Noatak delta. There is siderable variation in the vegetation, but in general it resembles tundra. In addition to a fairly typical array of wet tundra species umber of salt tolerant species are found, of which the following are t important: Zannichellia palustris, Carex spp., Atriplex gmelini, nula borealis, and Saussurea nuda. In the more exposed outer portions the delta, the marsh gives way to extensive mud flats which support tle or no vegetation.

Intertidal zone

Young, 1974

In the more exposed outer portions of the Noatak delta the marsh gives way to extensive mud flats supporting little or no vegetation.

McRoy, 1968

Zostera marina occurs in shallow water in Lopp and Ikpek lagoons on the western part of the north coast of the Seward Peninsula. This is apparently the northern limit of this species in Alaska.

Vegetation maps

Johnson *et al*. (1966) provide a vegetation map of the Ogotoruk Creek drainage (Plate 5, in back pocket).

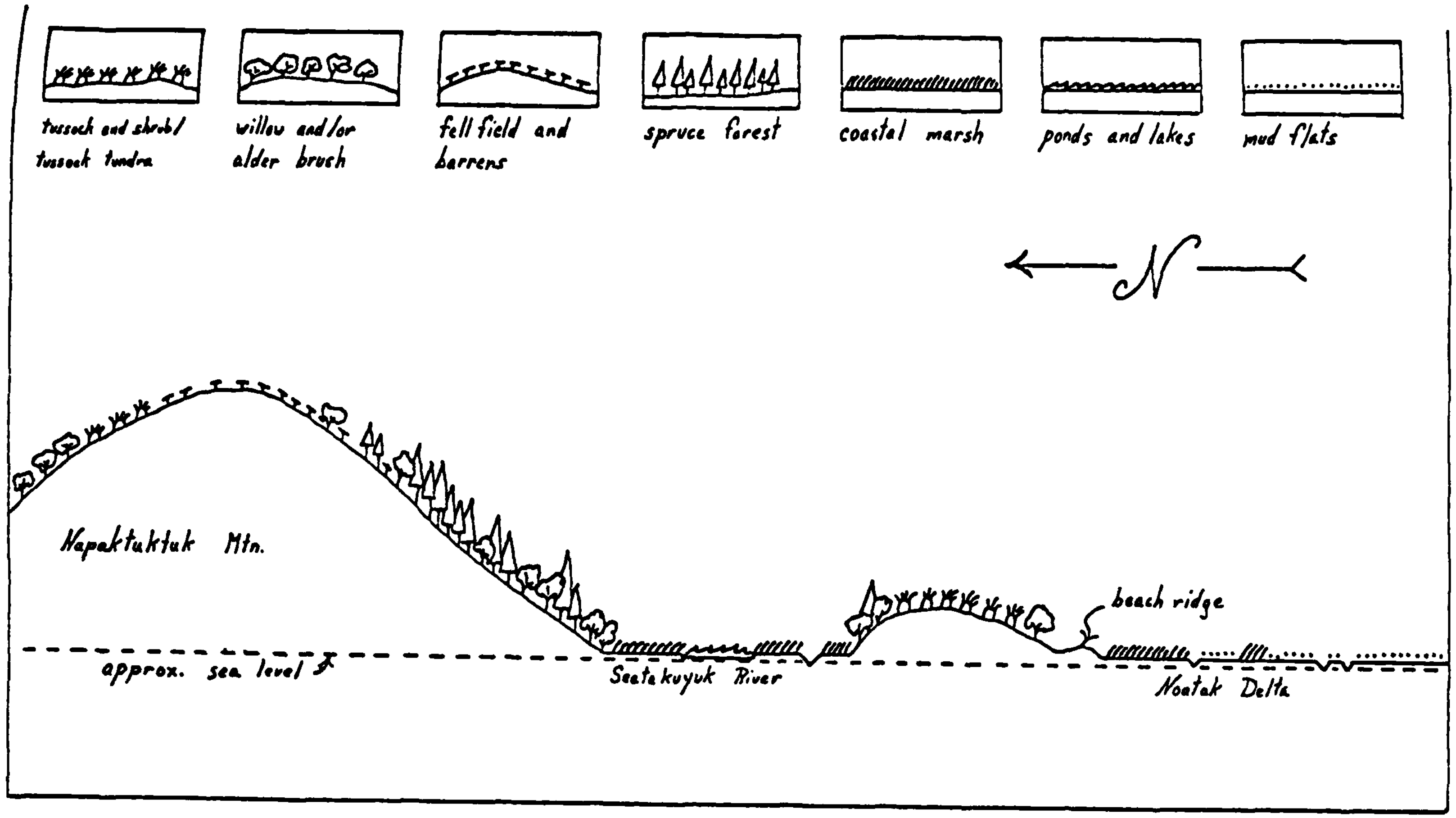


Figure 10. Generalized picture of the vegetation encountered in a transect from outliers of the Igichuk Hills to the mud flats of the Noatak delta. The total length of this transect would be about three miles. Drawing not to scale. (From Young, 1974, figure 1, p. 64.)

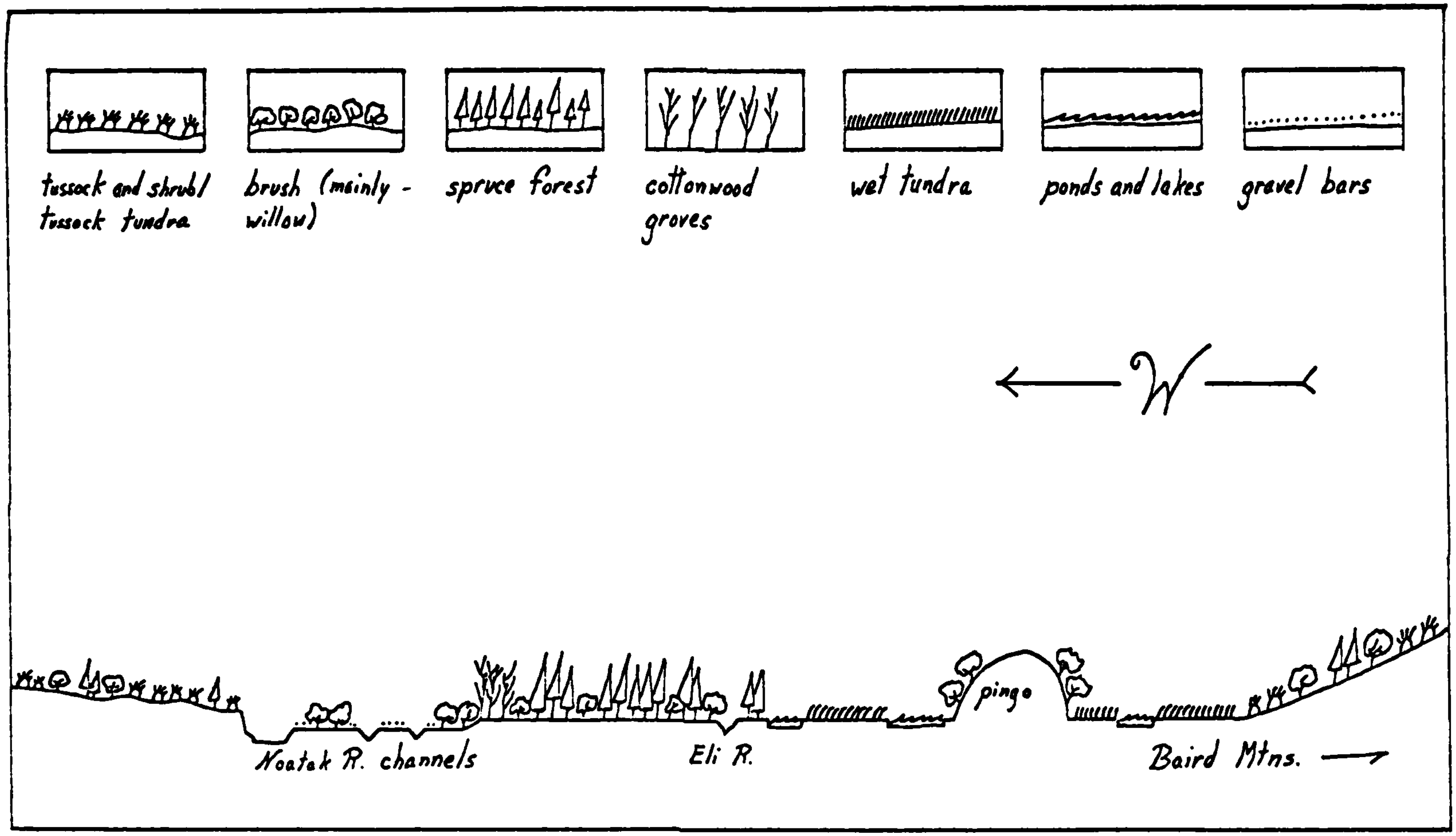


Figure 11. Generalized picture of the vegetation encountered in a transect across the Mission Lowland in the Noatak River valley. The length of the transect would be about 15 miles. Drawing not to scale. (From Young, 1974, figure 2, p. 65.)

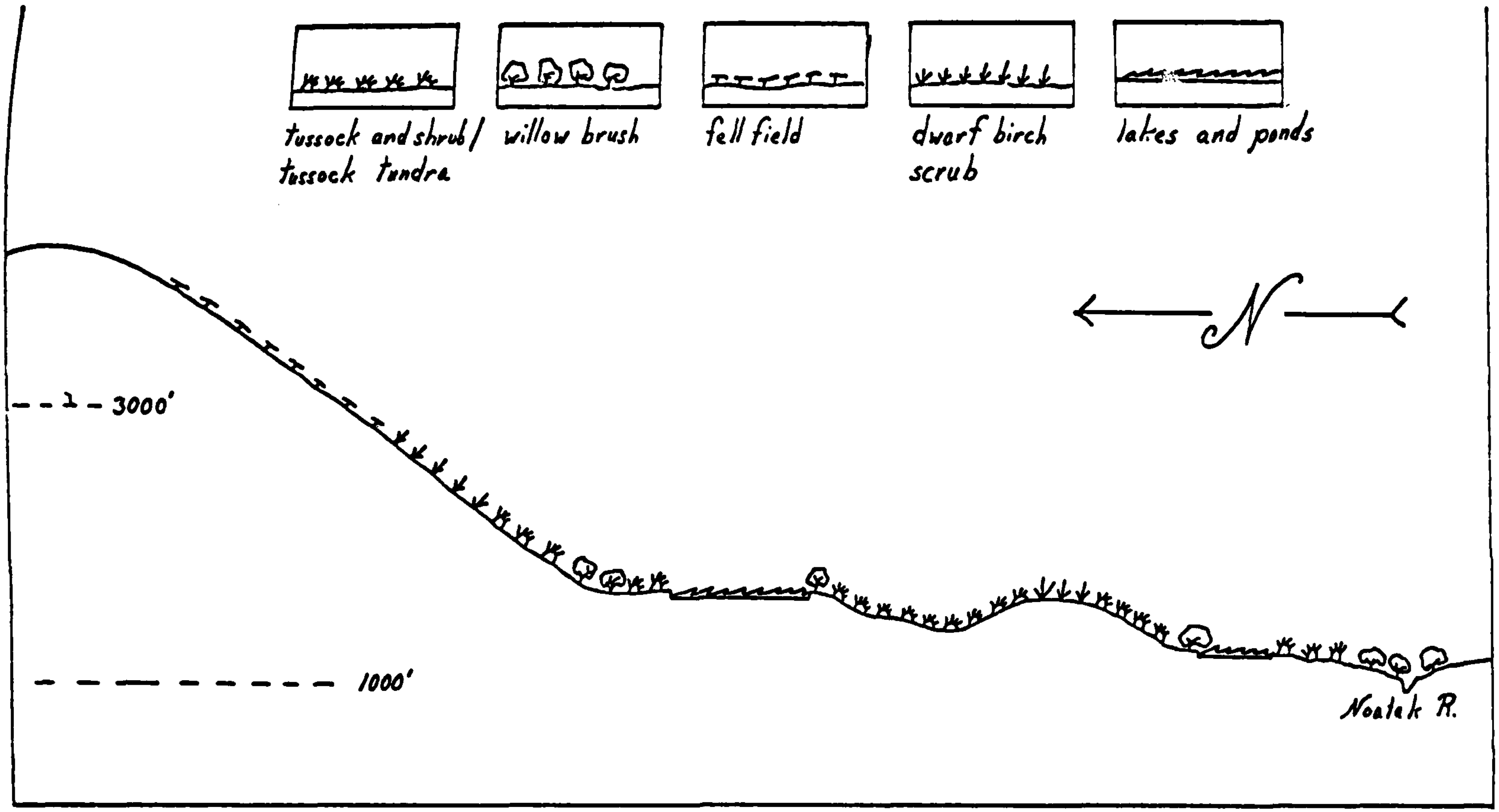


Figure 12. Generalized picture of the vegetation encountered in a transect from the Delong Mountains in the vicinity of Feniak Lake across the northern portion of the Aniuk Lowland to the main channel of the Noatak River. The length of the transect would be about 15 miles. Drawing not to scale. (From Young, 1974, figure 3, p. 66.)

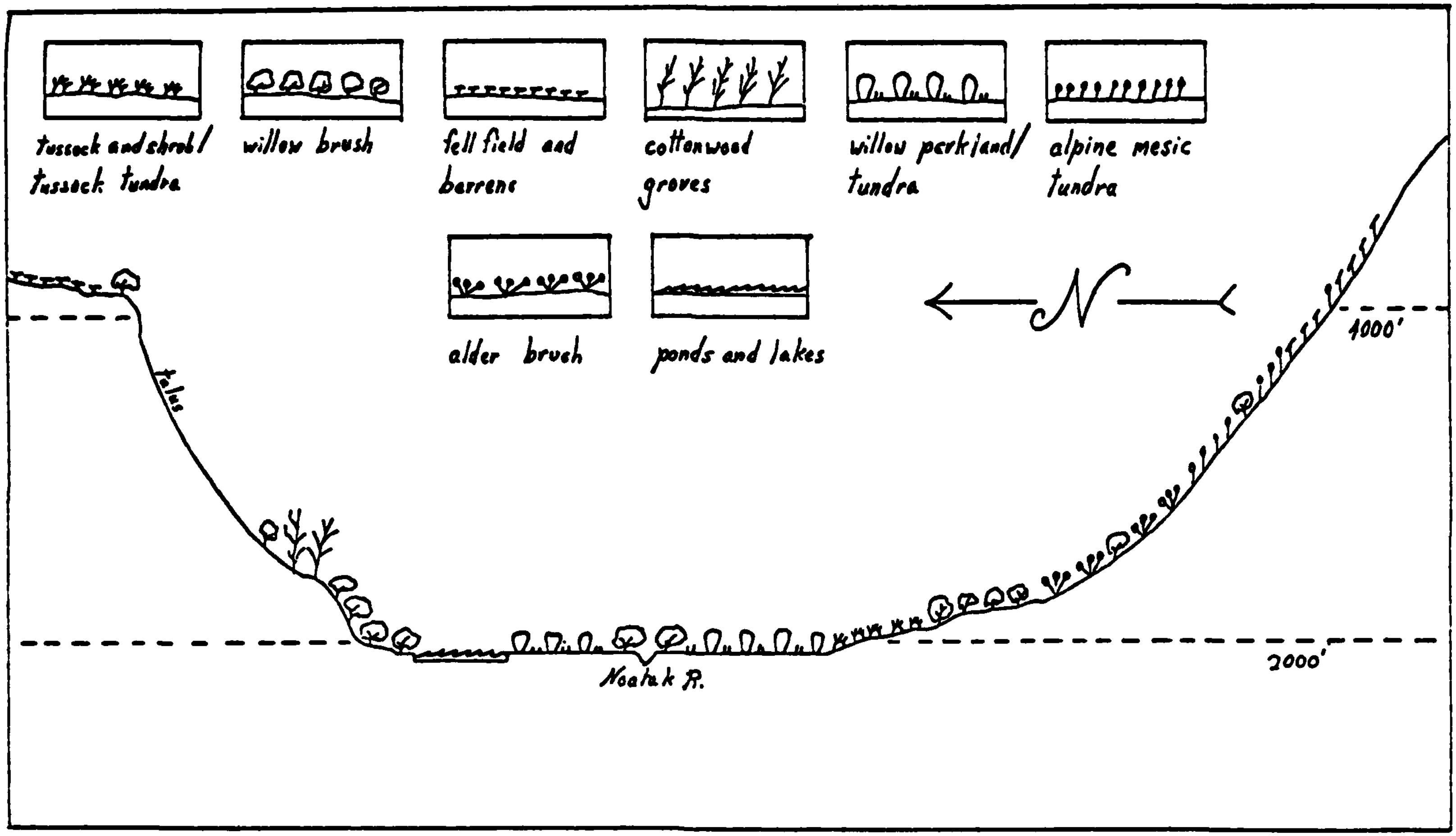


Figure 13. Generalized picture of the vegetation encountered in a transect across the Noatak River valley near the headwaters. The length of the transect would be about four miles. Drawing not to scale. (From Young, 1974, figure 4, p. 67.)

BEAUFORT SEA

The Arctic Coastal Plain extends inland along the entire length of the Beaufort Sea coast and a small part of the Chukchi Sea coast which is included in the Beaufort Sea region in this report. This lowland, which occupies roughly half of this region, is a narrow strip a few miles across in the east but is 100 mi across south of Barrow. The remainder of this region consists of the low rounded hills of the northern foothills and the rugged peaks of the Brooks Range. Small cirque and valley glaciers occur in the Brooks Range at the present time. During the Pleistocene, large valley and piedmont glacier systems spread from the mountains out into the foothills and rarely reached portions of the coastal plain. Consequently, most of the coastal plain and the uplands of the foothills have never been glaciated. Nevertheless, the coastal plain was submerged beneath the sea during the Quaternary (Sellmann and Brown, 1973). Continuous permafrost underlies the entire region. On the coastal plain the active layer (depth of annual thaw) is 0.5 to 4 ft thick, the permafrost itself being at least 1000 ft thick (Wahrhaftig, 1965). Polygons, both high- and low-center, are conspicuous in the lowlands of this region. The centers, or pans, of low-center polygons are often seasonally or permanently flooded; the margins are outlined by wet troughs which overlie the ice wedges.

Several large rivers drain the northern slopes of the Brooks Range and have built sizable deltas where they enter the Arctic Ocean. Thaw lakes are abundant on the coastal plain, and in the Teshekpuk Lake section (that part of the coastal plain west of the Colville River) lakes occupy

more than 50% of the land surface in many areas and up to 90% in others (Britton, 1967). Oxbow lakes are common on floodplains and several large moraine-dammed lakes are found in glaciated valleys in the Brooks Range.

Tidal fluctuation in the region is extremely weak; extreme high and low tides reach only 0.8 ft above and 0.2 ft below mean sea level (Johnson and Hartman, 1969). In the fall of years when the pack ice has blown far off-shore, strong on-shore winds sometimes cause storm tides that raise the level of the sea several feet above normal tides. The Beaufort Sea normally freezes in early October at Point Barrow and does not break up there until middle or late July. The summer distribution of the pack ice is controlled primarily by winds. The pack is seldom far off-shore and in some years is pressed up against the shore all summer (Johnson and Hartman, 1969).

This region has an arctic climate with cool summers and cold winters. Winds are common in both summer and winter and fog is common along the coast in the summer. The average annual temperature varies from 12.5° F in the Brooks Range to well under 10° F at Barrow. Average annual precipitation varies from less than 10 inches on the coastal plain to 20 to 40 inches in the high peaks of the Brooks Range (Viereck and Little, 1975).

The vegetation of the region is almost entirely tundra except for scattered white spruce (<u>Picea glauca</u>) groves in the heads of valleys on the south side of the Brooks Range that are included within the boundaries of this region. No spruce grow north of the Brooks Range but balsam poplar (<u>Populus balsamifera</u>) is found in sheltered locations on floodplains in the mountains and foothills of the north slope. Tall willows (primarily <u>Salix alaxensis</u>) are also abundant along stream courses in the mountains

and foothills but decrease in stature and frequency northward through the coastal plain. As in the Chukchi Sea region, the tundra vegetation is strongly influenced by microtopography such as hummocks and polygonal ground and by substrate instability due to frost action.

References to Beaufort Sea Wetlands

Andersson, Malte. 1973. Birds of Nuvagapak Point, northeastern Alaska. Arctic 26(3):186-197.

Bliss, L. C. and J. E. Cantlon. 1957. Succession on river alluvium in northern Alaska. Am. Midl. Nat. 58:452-469.

Britton, Max E. 1967. Vegetation of the arctic tundra, pp. 67-130. In Hansen, H. P., ed., Arctic Biology, 2nd ed. Oregon State University Press, Corvallis.

Brown, J., F. A. Pitelka, and H. N. Coulombe. 1970. A word model of the Barrow ecosystem, pp. 41-43. In Fuller, W . A. and P. G. Kevan, eds., Proceedings of the Conference on Productivity and Conservation in Northern Circumpolar Lands. International Union for Conservation of Nature and National Resources, Morges, Switzerland.

Churchill, Ethan D. 1955. Phytosociological and environmental characteristics of some plant communities in the Umiat region of Alaska. Ecology 36(4):606-627.

Clebsch, E. E. C. 1957. The summer season climatic and vegetational gradient between Point Barrow and Meade River, Alaska. Univ. of Tennessee M.S. thesis. 60 p.

Craig, P. C. and P. J. McCart. 1975. Classification of stream types in Beaufort Sea drainages between Prudhoe Bay and the Mackenzie Delta, N. W. T., Canada. Arctic and Alpine Research 7:183-198.

Drew, James V. and Royal E. Shanks. 1965. Landscape relationships of soils and vegetation in the forest-tundra ecotone, upper Firth River Valley, Alaska-Canada. Ecol. Monogr. 35:285-306.

Johnson, Phillip L. and Larry L. Tieszen. 1973. Vegetative research in arctic Alaska, p. 169-198. In Britton, M. E., ed., Alaskan Arctic Tundra. Arctic Inst. North America Tech. Pap. No. 25.

Kessel, Brina and Tom J. Cade. 1958. Birds of the Colville River, northern Alaska. Biol. Pap. Univ. Alaska No. 2. 83 p.

Koranda, John J. 1960. The plant ecology of the Franklin Bluffs area, Alaska. Univ. of Tennessee Ph.D. thesis. 234 p.

Koranda, John J. 1973. The north slope, its physiography, fauna, and its flora. Alaska Geographic 1:6-37.

Koranda, John J. and Charles D. Evans. 1975. A discussion of sites recommended as potential natural landmarks in the Arctic Lowland Natural Region, northern Alaska. Tundra Biome Center, University of Alaska, Fairbanks. 189 p.

Neiland, Bonita J. and Jerome R. Hok. 1975. Vegetation of the Prudhoe Bay region, p. 73-78. In Brown J., ed., Ecological Investigations of the Tundra Biome in the Prudhoe Bay Region, Alaska. Biol. Pap. Univ. Alaska Special Report No. 2.

Porter, Stephen C. 1966. Pleistocene ecology of Anaktuvuk Pass, Central Brooks Range, Alaska. Arctic Inst. North America Tech. Pap. No. 18. 100 p.

Potter, Loren D. 1972. Plant ecology of the Walakpa Bay area, Alaska. Arctic 25:115-130.

Schamel, Douglas L. 1974. The breeding biology of the Pacific Eider (Somateria mollissima v-nigra Bonaparte) on a barrier island in the Beaufort Sea, Alaska. Univ. of Alaska M.S. thesis. 95 p.

Shacklette, Hansford T. 1965b. Bryophytes associated with mineral deposits and solutions in Alaska. U.S. Geol. Surv. Bull. 1198-C. 17 p.

Smith, David K. 1974. Floristic, ecologic, and phytogeographic studies of the bryophytes in the tundra around Barrow, Alaska. Univ. Tennessee Ph.D. thesis. 191 p.

Spetzman, Lloyd A. 1951. Plant geography and ecology of the arctic slope of Alaska. Univ. of Minnesota M.S. thesis. 186 p.

Spetzman, Lloyd A. 1959. Vegetation of the arctic slope of Alaska. U.S. Geol. Surv. Prof. Pap. 302-B. 58 p.

Walker, Donald A. and Patrick J. Webber. 1973. Personal communication, vegetation map IBP study area, Barrow, Alaska.

Webber, Patrick J. and Donald A. Walker. 1975. Vegetation and landscape analysis at Prudhoe Bay, Alaska: a vegetation map of the Tundra Biome study area, p. 81-91. In Brown, J., ed., Ecological Investigations of the Tundra Biome in the Prudhoe Bay Region, Alaska. Biol. Pap. Univ. Alaska Special Report No. 2.

Weller, M. W. 1976. Personal communication and xerox materials.

Wiggins, Ira L. 1951. The distribution of vascular plants on polygonal ground near Point Barrow, Alaska. Contr. Dudley Herb. 4:41-56.

Wiggins, Ira L. and Donald G. MacVicar. 1958. Notes on the plants in the vicinity of Chandler Lake, Alaska. Contr. Dudley Herb. 5:69-95.

Wiggins, Ira L. and John Hunter Thomas. 1962. A flora of the Alaskan Arctic Slope. Arctic Institute of North America Special Publ. No. 4. University of Toronto Press, Toronto. 425 p.

Pond and lake

Andersson, 1973

Small ponds are common at Nuvagapak Point and within the sedge-grass marsh vegetation type. They are generally only .5 to 1 m deep and probably freeze to the bottom in winter. Underwater vegetation is sparse and the bottom consists of peat and detritus.

Britton, 1967

Strictly aquatic vegetation is not common in the mountains of the Brooks Range, although some lakes have zones of Arctophila fulva and Sparganium hyperboreum. The former often grows in water 5 to 6 ft deep with such species as Hippuris vulgaris, Eriophorum angustifolium, Alopecurus alpinus, and Caltha palustris occupying shallow inshore waters.

In the foothills, aquatic vegetation consists mainly of rooted emergent species distributed in zones correlated with water depth. Infrequently, the submerged species Potamogeton alpinus, P. filiformis, and P. pectinatus are found. The most consistent species in lakes around Umiat include Sparganium hyperboreum, Hippuris vulgaris, Menyanthes trifoliata, and Potentilla palustris. Sparganium occurs in about 3 ft of water; various mixtures of Menyanthes, Equisetum limosum, and Arctophila fulva occur in water 2 ft deep; Potentilla and Hippuris are found in water about 1 ft deep; and Carex spp. and Eriophorum spp. grow in shallower water around the margins. Other aquatic species are Ranunculus pallasii, R. gmelini, and Utricularia macrorrhiza.

On the Arctic Coastal Plain, the land becomes increasingly a landscape

of lakes, ponds, and marshes. Soils, even on the best drained sites, are saturated during much of the growing season. Ponds contain Arctophila fulva, often with a mixture of Hippuris vulgaris and Ranunculus pallasii.

Clebsch, 1957

At Point Barrow, Arctophila fulva grows in water from 1 to 2 m deep.

Johnson and Tieszen, 1973

The following community types are found in lakes and ponds at Meade River: open water, emergent grass, aquatic sedges, wet sedge bog, string bog, Sphagnum hummocks, and pond margin.

Kessel and Cade, 1958

The tundra component of the tundra-lacustrine water edge type is usually sedge-grass marsh, but in some places tussock-heath tundra also grows right up to the pond margins. This is an extensive habitat, especially in the low coastal tundra regions, where lacustrine waters comprise roughly one-third of the total surface area. At higher elevations in the foothills it is a much less important habitat, but it is common in bottomlands along rivers.

Koranda, 1960

Ponds with emergent vegetation occur in the Franklin Bluffs area.

Porter, 1966

Many of the numerous small lakes of the Anaktuvuk Pass area contain marginal aquatic vegetation, principally Carex aquatilis and Eriophorum angustifolium.

Potter, 1972

At Walakpa Bay Arctophila fulva is common in mud and wet gravel along the margins of lakes, pools, and streams in water up to 3 ft deep and extends along the depressions between polygons. Also in lakes and pools Hippuris vulgaris, Ranunculus pallasii, and R. gmelini are found.

Spetzman, 1951, 1959

Aquatic habitats are most extensive on the coastal plain where lakes make up about 20% of the surface. The footnills are better drained, and most of the lakes are of the oxbow type along major streams. In the mountains there are oxbow lakes along valleys, and at the mountain front a series of large lakes have been formed by moraine dams across valleys: Kurupa, Chandler, Shainin, Galbraith, Schrader, and Peters lakes. The bottom sediment is usually muck, although recently formed oxbow lakes and some mountain lakes have sand or boulder bottoms. Shores have ice-push ridges. Vascular aquatic species are few in number, and very little aquatic growth occurs in water more than 4 ft deep. Each lake possesses a set of aquatic plants slightly different from others. The depth zone preferred by any given species becomes more shallow as one goes

:hward from the foothills into more severe climatic conditions. :ed submerged aquatics are relatively unimportant and often lacking. :ed emergent aquatics are common and play a role in the filling- ›f lakes through the accumulation of peat from their dead parts, resulting ıtually in the formation of a bog meadow.

The principal submerged rooted aquatics (in up to 4 ft of water) are: 'ganium hyperboreum, Ranunculus gmelini, and Potamogeton spp. Emergent :ed aquatics (in up to 3 ft of water) are: Arctophila fulva (frequently most important plant in a lake), Hippuris vulgaris, Potentilla ıstris, Ranunculus pallasii, Menyanthes trifoliata, and Equisetum ›sum (Umiat). Marginal emergent aquatics (in up to 1 ft of water) Carex aquatilis (usually most important), Caltha palustris, ›phorum angustifolium (usually present), and Alopecurus alpinus.

Walker and Webber, 1973

At Barrow pond and stream margins are vegetated with Arctophila fulva.

Webber and Walker, 1975

At Prudhoe Bay the deeper waters of thaw lakes are unvegetated. ophila fulva and/or Carex aquatilis grow in water 30 to 100 cm deep g the margins of lakes and in thermokarst pits.

Weller, 1976

The following wetland classes may be considered ponds and lakes: hallow Carex ponds. The water is 10 to 30 cm deep and Carex aquatilis

is the dominant species. 2) Shallow *Arctophila* ponds (*A. fulva*). The water is 20 to 50 cm deep. The *Arctophila* grows in the central part of the pond, and turns red by late June. 3) Deep *Arctophila* ponds and lakes. The water is more than 40 cm deep. The *Arctophila* grows near the shore leaving the deeper water in the center unvegetated. 4) Deep open lakes. These are large deep lakes (maximum water depth 110 cm) with abrupt shores. *Arctophila* is absent or occupies less than 5% of shoreline. 5) Beaded streams. The "bead" ponds may be vegetated with *Carex aquatilis* and *Arctophila fulva* in the shallow water near the edges and with *Arctophila fulva* in deeper water of the centers.

Wiggins and MacVicar, 1958

In shallow water, particularly at the northern end of Big Chandler Lake and along the shores of Little Chandler, at a number of places,are extensive stands of *Arctophila fulva*, with a minor admixture of *Eriophorum angustifolium*, *Caltha palustris*, *Ranunculus pallasii*, and *R. hyperboreus*. Pools a few centimeters in depth in low swales on boggy, low-relief areas of the main deltas around Chandler Lake support several species of *Carex*, *Ranunculus pallasii*, *Caltha palustris*, *Arctophila fulva*, *Eriophorum angustifolium*, and *E. scheuchzeri*.

Wiggins and Thomas, 1962

Comparatively few aquatic vascular plants grow in the Alaskan Arctic, but species of *Hippuris* and *Potamogeton* are occasionally found. *Arctophila fulva* is a common emergent aquatic that grows in water up to 3 or 4

ft deep. It appears that the pH of the water affects the color of this plant. In water with a pH between about 5 and 5.4 it grows with bright green leaves and stems, but in water between pH 6 and 7 it is bright red.

In ponds and pools near Umiat the following species may occur:

Menyanthes trifoliata	Ranunculus hyperboreus
Sparganium hyperboreum	R. gmelini
Caltha palustris	R. pallasii

Fresh water marsh

Two basically different types of vegetation are included in this category. These are 1) a type on wet alluvium, dominated by non-tussock-forming species of Carex and Eriophorum, and 2) a type on interfluves dominated by the tussock-forming Eriophorum vaginatum.

Andersson, 19/3

Tussock-heath tundra is widely distributed in the Nuvagapak Point vicinity, especially at the elevated point, which is better drained than the surroundings.

Churchill, 1955

The Carex aquatilis-marsh type sometimes occurs on mineral soils. In addition to Carex aquatilis, Eriophorum angustifolium, Salix fuscescens, and Caltha palustris are characteristic.

Drew and Shanks, 1965

On the Firth River the "solifluction fan with scattered spruce" landscape unit is characterized by scattered scrubby white spruce, solifluction lobes, and soils sufficiently wet that water drains rapidly into soil pits. Permafrost is not present within 40 inches of the surface. The soil consists mainly of silts and clays and has developed over limestone. It is classified as calcareous low humic gley. Abundant species on these sites include:

Equisetum arvense	Carex lugens
E. palustre	C. physocarpa
Camptothecium sp.	C. membranacea

The upland tussock tundra landscape unit consists of the rounded surfaces of a dissected bedrock terrace, with a 3 to 10% slope that stands above the floor of the valley. Tussocks of Eriophorum vaginatum and a microrelief pattern of mounds 2 to 4 ft in diameter and 4 to 12 inches high characterize this unit. Occasional frost boils occur between the mounds and tussocks. The soil is composed mostly of silty clay mineral material. Although the thawed portion of this soil is acid it apparently is derived from limestone parent material, since limestone is exposed at the edge of the unit. Frozen ground at 20 inches prevented digging to the parent material. Eriophorum vaginatum tussocks dominate the aspect and cover about 40% of the surface of this unit. Characteristic associates include:

Betula glandulosa	Vaccinium uliginosum
Ledum palustre	V. vitis-idaea
Empetrum nigrum	Arctostaphylos alpina
	Salix reticulata

The sedge meadow terrace landscape unit occurs on broad terraces of calcareous alluvium. Ice-wedge polygons occur at the terrace edges but become less conspicuous farther back. Other microrelief features include frost boil peat rings, mounds, and occasional low tussocks. Frozen ground was found at a depth of 20 inches. The soil consisted of a 7-inch peat and humus layer overlying a dark gray-brown calcareous silty clay that had developed over calcareous sands and gravels. Carex lugens and other species of Carex constitute the bulk of the vegetation. Also important are Eriophorum angustifolium and E. vaginatum. Most of this unit is free of standing water in midsummer, but it merges with wetter landscape units.

Kessel and Cade, 1958

Sedge-grass marsh is found on mineral soils or on peat in low, flat, poorly drained terrain, particularly around ponds or lakes, predominantly on the coastal plain. The dominant plants are Carex aquatilis, other species of Carex, and grasses.

Silt deposits are extensive along the Colville River between the mouth of the Itkillik River and the Arctic Ocean and are more limited in areas where silts overlie gravels, as along the Colville River upstream from the Itkillik. When not inundated by high water these sites support stands of Equisetum and Carex; otherwise they are devoid of vegetation.

Koranda, 1960

At Franklin Bluffs the basic marsh wetlands are upland sedge-tussock meadow (the wettest portions) and wet sedge meadows.

Koranda and Evans, 1975

On uplands on the interfluves between major rivers, marshy types include: 1) Sedge tussock tundra, dominated by Eriophorum vaginatum with low shrubs, grasses, and herbs; 2) Coastal sedge-grass tundra, dominated by non-tussock-forming Eriophorum, Carex, Dupontia, and Arctophila.

In major river valleys, swales and marshes of sedges and grasses are found in abandoned stream channels and filled-in oxbow lakes.

Smith, 1974

Mesic bryophyte communities occur on the beachslope sector of the study transect at Barrow. 1) The Distichium capillaceum community occurs primarily in the middle of the beachslope but shows a slight tendency toward growth on elevated soil mound sites. The relative soil moisture ranges from 25% to 275%. 2) The Drepanocladus revolvens-Distichium capillaceum-Oncophorus virens community occurs primarily in the lower portion of the beachslope and sometimes in depressions in the middle and upper portions of the beachslope. The relative soil moisture averages about 250%. 3) The Hylocomium splendens var. obtusifolium-Drepanocladus uncinatus-Tomenthypnum nitens-Ptilidium ciliare community is most abundant in the upper portion of the beachslope.

Spetzman, 1951, 1959

Niggerhead meadows are found along the southern margin of the coastal plain, over the entire foothills, and into the mountains along some of the larger valleys, usually below 3000 ft. Drainage is moderate, although

northward from the foothills into more severe climatic conditions. Rooted submerged aquatics are relatively unimportant and often lacking. Rooted emergent aquatics are common and play a role in the filling-in of lakes through the accumulation of peat from their dead parts, resulting eventually in the formation of a bog meadow.

The principal submerged rooted aquatics (in up to 4 ft of water) are: Sparganium hyperboreum, Ranunculus gmelini, and Potamogeton spp. Emergent rooted aquatics (in up to 3 ft of water) are: Arctophila fulva (frequently the most important plant in a lake), Hippuris vulgaris, Potentilla palustris, Ranunculus pallasii, Menyanthes trifoliata, and Equisetum limosum (Umiat). Marginal emergent aquatics (in up to 1 ft of water) are: Carex aquatilis (usually most important), Caltha palustris, Eriophorum angustifolium (usually present), and Alopecurus alpinus.

Walker and Webber, 1973

At Barrow pond and stream margins are vegetated with Arctophila fulva.

Webber and Walker, 1975

At Prudhoe Bay the deeper waters of thaw lakes are unvegetated. Arctophila fulva and/or Carex aquatilis grow in water 30 to 100 cm deep along the margins of lakes and in thermokarst pits.

Weller, 1976

The following wetland classes may be considered ponds and lakes:

1) Shallow Carex ponds. The water is 10 to 30 cm deep and Carex aquatilis

is the dominant species. 2) Shallow *Arctophila* ponds (*A. fulva*). The water is 20 to 50 cm deep. The *Arctophila* grows in the central part of the pond, and turns red by late June. 3) Deep *Arctophila* ponds and lakes. The water is more than 40 cm deep. The *Arctophila* grows near the shore leaving the deeper water in the center unvegetated. 4) Deep open lakes. These are large deep lakes (maximum water depth 110 cm) with abrupt shores. *Arctophila* is absent or occupies less than 5% of shoreline. 5) Beaded streams. The "bead" ponds may be vegetated with *Carex aquatilis* and *Arctophila fulva* in the shallow water near the edges and with *Arctophila fulva* in deeper water of the centers.

Wiggins and MacVicar, 1958

In shallow water, particularly at the northern end of Big Chandler Lake and along the shores of Little Chandler, at a number of places,are extensive stands of *Arctophila fulva*, with a minor admixture of *Eriophorum angustifolium*, *Caltha palustris*, *Ranunculus pallasii*, and *R. hyperboreus*. Pools a few centimeters in depth in low swales on boggy, low-relief areas of the main deltas around Chandler Lake support several species of *Carex*, *Ranunculus pallasii*, *Caltha palustris*, *Arctophila fulva*, *Eriophorum angustifolium*, and *E. scheuchzeri*.

Wiggins and Thomas, 1962

Comparatively few aquatic vascular plants grow in the Alaskan Arctic, but species of *Hippuris* and *Potamogeton* are occasionally found. *Arctophila fulva* is a common emergent aquatic that grows in water up to 3 or 4

standing water may be present in spring. The primary species is the tussock-forming Eriophorum vaginatum. Small frost boils frequently contain Chrysosplenium wrightii, Festuca brachyphylla, and Juncus biglumis.

Webber and Walker, 1975

Moist streamsides at Prudhoe Bay are characteristically vegetated by Carex aquatilis, Dupontia fisheri, and Saxifraga hirculus.

Peatland

Andersson, 1973

Sedge-grass marsh (probably with peaty soils) covers most of the area around Nuvagapak Point. It is wet, with many ponds, and several centimeters of standing water after snow melt in June. Species of Carex dominate the vegetation.

Britton, 1967

In the Brooks Range the wettest terrain of the lowlands, adjacent to streams and lakes, is occupied by wet boggy meadows vegetated chiefly by Carex aquatilis, Carex spp., Eriophorum scheuchzeri, Juncus spp., Equisetum palustre, Andromeda polifolia, and Salix spp. These areas are frequently interspersed with areas of tussock vegetation.

On the Arctic Coastal Plain lake basins and their gently sloping divides are the most widespread features of the landscape. Any adequate understanding of these surfaces can accrue only through intimate knowledge

of the geomorphic processes which create, modify, and destroy not only the basins and divides but the multitude of minor relief features as well.

The communities of the Teshekpuk Lake section have not been objectively differentiated. In general, going from south to north on the Arctic Coastal Plain, there is some reduction in the total number of species constituting the flora; there is a marked reduction in woody species, particularly the heaths; there is a conspicuous increase in the absolute and relative abundance of grasses and sedges; and the land is increasingly a landscape of lakes, ponds, marshes, and soils which even on the best-drained sites are saturated during much of the warm season. The general increase in vegetation of a wet grassland type on nearly all surfaces is paralleled by an increase in terrain of the poorest drainage and by taxa that are increasingly hydrophytic. Differences between the vegetation of uplands and lowlands, at least in terms of composition, become less and less pronounced. All of the species of the extensive marshes also occur on the uplands, and most of those of the driest upland sites are to be found wherever hummocks occur within the wetter areas. It would be difficult to imagine an area equal to that of the lake section in which populations are so ubiquitous and the differentiation of vegetation so dependent upon micro-relief. The vegetation is conspicuously a mosaic of recurring assemblages distributed over and differentiated by the geomorphic structures of patterned ground. Much, but not all, of the upland vegetation is more complex by reason of the relatively greater age of surface, greater geomorphic differentiation, and consequent greater range of habitats.

The extremes of wet and dry sites have well-differentiated cover, but

intergradations are so common over short distances that classification of vegetation at present is essentially hopeless. Dry habitats occur only on the most elevated peat mounds or on local silt mounds where drainage has developed along polygon troughs. Extensive marshy areas occur even on the highest divides, and the vegetation within them is equally characteristic of certain of the adjacent drained basins. Variability in populations, especially with regard to subdominants, is great not only over large areas but also within distances of only a few feet on terrain of marked microtopographic expression. It cannot, however, be overstressed that the distribution patterns, while variable, have limits and are highly repetitive.

Communities are simplest in the marshy lowlands where standing water, as relatively large lakes or small permanent and even intermittent ponds, is abundant. Shorelines typically have communities of Arctophila fulva, Carex aquatilis, Eriophorum scheuchzeri, E. angustifolium, Dupontia fisheri, and Alopecurus alpinus which may occur as essentially pure stands or in various mixtures between certain of the species. The larger and deeper lakes usually lack emergent vegetation, but the shallowest ones have a dense cover. Along gradients extending from water 5 to 6 ft deep, through shallow water, to saturated soils only seasonally swamped, the distribution of species follows a rather consistent pattern of Arctophila, Eriophorum spp., Carex, and Dupontia. The distribution of Alopecurus in this sequence is uncertain, but it is apparently a near equivalent of Dupontia. [This sequence is clearly a successional series in Britton's view, although one or more of the communities is often entirely absent or may be discontinuous in distribution in a particular lake.]

Brown _et al._, 1970

At Barrow, meadows and polygon troughs on meadow tundra and bog soils are vegetated with _Dupontia fisheri_, _Carex aquatilis_, _Eriophorum angustifolium_, _E. scheuchzeri_, _Petasites frigidus_, and _Poa arctica_.

Churchill, 1955

Part of the _Carex aquatilis_ marsh type may occur on peaty soils. In addition to the above-named dominants, _Eriophorum angustifolium_, _Salix fuscescens_, and _Caltha palustris_ consistently occur. These sites are found both on the uplands and on floodplains, often occupying broad, shallow drainageways on the former and abandoned sloughs and filled-in oxbow lakes on the latter.

Clebsch, 1957

At Nuwuk grassy flats and the pans of low-center polygons are characterized by _Dupontia fisheri_, _Carex aquatilis_, _Eriophorum scheuchzeri_, and _E. angustifolium_. Of these, _Dupontia fisheri_ is by far the most abundant. At Inaru River a low-center polygon is vegetated primarily by _Carex aquatilis_, _Salix pulchra_, and _Salix phlebophylla_. At Meade River both the shallow, low-center polygon pans and the interpolygonal troughs are vegetated chiefly by _Carex aquatilis_.

Drew and Shanks, 1965

At the Firth River the calcareous bog meadow and strangmoor landscape unit occurs on terraces that receive drainage water from adjacent

calcareous slopes and solifluction fans. The soils consist of moss and sedge peat overlying calcareous alluvium; standing water is present locally. This unit includes two vegetation types. Bog meadow exhibits no appreciable microrelief whereas strangmoor consists of bog meadow with peat ridges. In general, these ridges are perpendicular to an almost imperceptible slope and are usually spaced 3 to 50 ft apart. The peat layer in the area investigated is 17 inches thick and overlies a gray silt loam. Frozen ground was encountered at a depth of 25 inches. The bog meadow is vegetated primarily by sedges, as are the ponded areas, or flarks, between the ridges of the strangmoor. Water was typically ankle-deep in the flarks in early August. Vegetative cover ranges from a sparse sedge stand rooted in a semi-aquatic moss mat (Calliergon and Drepanocladus) to a continuous sward of sedges rooted in a peaty mat. Sedges common in the bog meadows and the strangmoor flarks include:

Carex aquatilis	Carex microglochin
C. chordorrhiza	Eriophorum scheuchzeri
C. limosa	E. angustifolium

The ridges of the strangmoor support many low shrubs; characteristic of these are:

Betula glandulosa	Rhododendron lapponicum
Arctostaphylos alpina	Vaccinium uliginosum
Salix arctica	

The noncalcareous bog meadow and strangmoor landscape unit occurs on terraces that receive drainage water from higher and strongly acid upland tundra soils. The soils of this unit are composed of moss and sedge peat

overlying gravelly alluvium; standing water is present locally. The peat ridges of this unit are larger than those of the calcareous strangmoor, consisting of peat accumulation as high as 2 ft with widths of 6 to 10 ft. The soil consists of 2 ft of peat overlying gravel and was frozen at a depth of 21 inches. In contrast with the calcareous bog meadow and strangmoor, this unit is characterized by more surface water, less pronounced sedge dominance, and larger ridges and islands. The ridges and islands are made up of Sphagnum peat and support acid-habitat shrubs such as Betula glandulosa, Rubus chamaemorus, Ledum palustre, and Vaccinium vitis-idaea. [A diagram showing the major landscape units of the upper Firth River valley is reproduced here as figure 14.]

Kessel and Cade, 1958

Sedge-grass marshes are found on low, flat, poorly drained terrain, particularly around ponds and lakes and predominantly on the coastal plain. Marshes are also found in depressions or sinks in the uplands and in the low centers of ice-wedge polygons. Sedge-grass marshes are characterized by the high moisture content of the substrate of mineral soil or peat; sometimes several inches of standing water are present. [A cross-sectional diagram of the Colville River and adjacent uplands near Umiat is reproduced here as figure 15.]

Koranda, 1960

A sedge marsh or swale type and a wet sedge meadow type occur at Franklin Bluffs.

Koranda and Evans, 1975

In the Arctic Lowland, on the interfluves between major rivers, swales narshes are dominated by grasses and sedges with some hydric herbs as Cardamine and Ranunculus. These occur in drainage channels on nds and in lake basins. Sedge and grass dominated marsh vegetation occurs on the floodplains of major rivers.

Neiland and Hok, 1975

Boggy landscape units at Prudhoe Bay include: 1) old lake beds out permanent standing water, although some ponds may be present; et or intermediately wet smooth plains, very uniform in appearance respect to both vegetation and microtopography; 3) indistinct old gons, but little microtopographic variation remains; 4) patterned plain nich vegetational but little microtopographic variation is apparent; ow-center polygons with the water table at or near the surface of the all season, bordered by raised ridges covered with dry springy mats egetation; 6) wet ridged plain which is similar to the wet smooth n, but interrupted by irregular ridges and hummocks 10 to 15 igh; 7) troughs (30 to 60 cm deep) separating high-center polygons.

Potter, 1972

Dupontia fisheri is important in low-centered polygon pans situated ne wet borders of the shallow ponds where the surface is only tempor- flooded. In wetter terrain Arctophila fulva dominates and other tant plants include Carex aquatilis, Eriophorum scheuchzeri, and E.

angustifolium.

Sedge-willow meadows occur on gentle slopes flanking the principal drainage channels. Most of the cover consists of Carex spp. and Salix rotundifolia.

Troughs between high-center polygons are vegetated with Carex aquatilis, Dupontia fisheri, and Petasites frigidus. In the low part of some troughs extensive mats of Sphagnum form deep, wet cover through which the graminoid plants emerge.

Smith, 1974

Six hydric bryophyte communities occur at Barrow: 1) the Scapania paludosa community grows only in the troughs between high-center polygons; 2) the Oncophorus wahlenbergii-Cephaloziella arctica community grows on the driest parts of wet low-center polygons; 3) the Cephaloziella arctica-Oncophorus wahlenbergii community is closely related to the preceding one and is found on the slopes of polygon ridges and interpolygonal troughs as well as on raised polygon margins and ridge tops; 4) the Cephaloziella arctica-Calliergon sarmentosum-Drepanocladus revolvens-Cinclidium subrotundum-Riccardia pinguis community occurs on wetter sites than the foregoing, such as interpolygonal troughs, trough slopes, and wet polygon margins where the relative soil moisture is near 500% and the pH mode-range is 4.85-5.05; 5) the Oncophorus wahlenbergii community also occurs in wet areas with relative soil moisture around 500%; 6) the Drepanocladus revolvens community has an average relative soil moisture of 610% and is found only in low-center polygon troughs.

Spetzman, 1951

Bog meadows occupy almost half of the Arctic Coastal Plain and about one-quarter of the foothills, but they are unimportant in the mountains. They occur primarily on flat, poorly drained lowlands and along the margins of lakes. The organic soil on which these meadows grow is saturated during most of the growing season and may have shallow standing water. The active layer is about 18 inches deep, and ice-wedge polygons are usually well developed. Species of Carex constitute about 75% of the bog vegetation. Any one of several Carex species may dominate in a given locality, but in general Carex aquatilis is by far the most important. Also present are C. chordorrhiza, C. rariflora, C. rotundata, C. membranacea, Dupontia fisheri (coastal), and Eriophorum scheuchzeri (coastal).

Spetzman, 1959

A list of common species found in wet sedge meadows on the arctic slope is given on page 25.

Walker and Webber, 1973

Four of the vegetation units at Barrow may be considered wet peatlands: 1) the Carex aquatilis-Eriophorum angustifolium-Dactylina arctica-Cetraria sp. community; 2) the Carex aquatilis-Eriophorum angustifolium-lichens (except Petigera aphthosa) community; 3) the Carex aquatilis-Dupontia fisheri community; and 4) the Dupontia fisheri-Calliergon sarmentosum community. The first three occur on the flat centers of weakly defined polygons; the fourth occurs on level expanses with impeded drainage and in troughs.

Possibly belonging here is the Salix rotundifolia-Arctagrostis latifolia-fruticose lichens type found on gently sloping creek banks.

Webber and Walker, 1975

Several vegetation units in the Prudhoe Bay area are found on wet peaty substrates: 1) low-center polygon pans are vegetated with Carex aquatilis and/or Eriophorum angustifolium, Drepanocladus brevifolius, and Pedicularis sudetica; 2) low-center polygon troughs with Carex aquatilis and Scorpidium scorpioides; 3) flat areas with Carex aquatilis and/or Eriophorum angustifolium, and Dryas integrifolia; and 4) lake margins dominated by Carex aquatilis and/or Arctophila fulva.

Weller, 1976

Flooded flats and seasonally flooded basins are commonly vegetated primarily by Carex aquatilis and Eriophorum angustifolium at Storkersen Point. Basins interspersed with C. aquatilis and Arctophila fulva are also common.

Wiggins, 1951

Troughs between high-center polygons at Barrow support dense stands of Dupontia fisheri and Carex aquatilis and the flat polygon pans are vegetated chiefly by a close sod of Dupontia fisheri with a few scattered plants of Carex aquatilis and Poa arctica. The troughs between these low-center polygons have Dupontia fisheri with a few individuals of Arctophila fulva in the wetter sites. In low-center polygons with

permanently flooded pans Arctophila fulva grows in water 30 to 40 cm deep; in shallower water Dupontia fisheri and Carex aquatilis intermingle with the Arctophila and eventually replace it on the polygon ridges.

Wiggins and Thomas, 1962

The following species are found in saturated soil adjacent to ponds:

Pedicularis sudetica	Valeriana capitata
P. langsdorffii	Eriophorum spp.
P. capitata	Juncus biglumis
Lagotis glauca	Carex spp.

Stream

Andersson, 1973

In the Nuvagapak Point area streams are 5 to 10 m wide during the snow-melt season, but the flow quickly decreases and by early July the river beds of coarse gravel are exposed.

Craig and McCart, 1975

The streams that flow into the Beaufort Sea between Prudhoe Bay and the Mackenzie Delta can be classified into three categories: 1) mountain streams that originate in the mountains and are large, braided, and often glacier-fed; 2) spring streams that originate at definite springs, such as Sadlerochit and Shublik springs; and 3) tundra streams that have their headwaters in tundra slopes of the foothills and coastal plain. It was noted that

grayling spawn only in tundra streams while char spawn in spring and mountain streams.

Spetzman, 1951

Most streams are too cold or too turbulent for aquatic plants.

Webber and Walker, 1975

No vegetation occurs in streams at Prudhoe Bay.

Riparian gravel bar and cutbank

Andersson, 1973

Dwarf shrub and tall brush communities do not occur at Nuvagapak Point. The few existing Salix shrubs are scattered and prostrate, and they are not associated with riparian habitats.

Bliss and Cantlon, 1957

A perennial herb community occurs on gravel bars of the Colville River near Umiat on sites less than 1.5 m above the midsummer flow level. The substrate is thawed to a depth greater than 1 m. The most abundant species are Crepis nana, Erigeron purpuratus, Epilobium latifolium, Artemisia tilesii, A. alaskana, A. arctica, Oxytropis sp., Astragalus alpinus, A. lepagei, and Lupinus arcticus.

Salix alaxensis is the first woody plant to become established in the perennial herb communities. If not destroyed by subsequent floods or erosion, these plants become dominant, forming young feltleaf willow communities.

These usually occur on islands and gravel bars a few feet above the perennial herb stands. The soils on these sites are still mostly sands and gravels with some mineral silts. Permafrost is deeper than 1 m or absent. The best development of this community occurs adjacent to the stream channel and usually on the upstream end of the bar. The herb layer is dominated by scattered clumps of Lupinus arcticus, Oxytropis sp., Hedysarum mackenzii, H. alpinum, Artemisia tilesii, and A. alaskana.

Decadent feltleaf willow (Salix alaxensis) communities represent a further stage in succession. They are characterized by large, scattered feltleaf willow clumps in which a high proportion of the stems are dead. Feltleaf willow (2 to 4 m high) still is the dominant species, but several of the greenleaf willows (up to 2 m high) present in the young feltleaf willow stage are more important; Salix arbusculoides is the most important of these. The contribution of Alnus crispa has also increased, but it is still the least important shrub.

Churchill, 1955

A Salix vegetation type characterized by Salix glauca and Petasites frigidus occurs on the upland at Umiat along small well-defined drainage channels. Other plants frequently present are Rubus chamaemorus and mosses, especially Sphagnum spp.

Drew and Shanks, 1965

At Firth River the floodplain with willow thickets landscape unit consists of a broad gravel floodplain with scattered willow thickets near

its edge. Aufeis covers much of the gravel during the winter and large masses of this ice persist during the summer. Thin local deposits of carbonates are left on the gravel surface as the aufeis thaws. The vegetation of the floodplain is composed of relatively few species. Those present are characteristic of the alpine tundra and Dryas terrace landscape units:

Dryas octopetala	Crepis nana
Anemone drummondii	Oxytropis gracilis
Lesquerella arctica	Carex scirpoidea

Other common and characteristic herbs and low shrubs include:

Epilobium latifolium	Festuca sp.
Hedysarum alpinum	Castilleja pallida
Juncus arcticus	Potentilla fruticosa
Bromus pumpellianus	Shepherdia canadensis

The scattered willow thickets attain a height of 6 to 15 ft. Salix alaxensis is common and often associated with S. glauca, S. richardsonii, and S. arbusculoides.

Kessel and Cade, 1958

Tall brush (woody plants higher than 3 ft) is entirely restricted to the slopes and terraces adjacent to major rivers of the foothills province; it is virtually absent from both the coastal plain and Brooks Range provinces. The dominant plants are willows and alders ranging in height from 3 to 30 ft (averaging 8 to 10 ft). Salix alaxensis occurs most frequently in pure stands on the alluvial gravels immediately adjacent

to the river, whereas alders mixed with greenleaf willows occur on the slopes and terraces of the main river and along tributary creeks in the foothills. Pure stands of alder occur on both poorly drained areas of the lower river terrace and on well-drained areas along the brink of river bluffs. Pure stands of greenleaf willows are found along some of the creeks in the bottom-lands and in the foothills.

Koranda, 1960

Pioneer forb-grass meadow with scattered willows occurs on Franklin Bluffs gravels; open willow thickets grow on alluvial fans and gravel bars.

Koranda and Evans, 1975

Grass-herb meadows are found on terraces and old gravel bars in major river valleys of the arctic lowlands. Thickets of Salix alaxensis occur on the active floodplains and on terraces.

Spetzman, 1951

On floodplain and cutbank areas near the foothills, there is a clear sequence of vegetational stages. The pioneer stage is characterized by many species (75 at Umiat), both woody and herbaceous. After 20 to 50 years large willows shade out most of the low-growing pioneers. Following the tall shrubs is a stage dominated by low willows and heaths accompanied by an accumulation of organic debris, abundant growth of mosses, and reduction of the depth of summer thaw due to the insulating vegetation blanket thus produced. The moss layer is probably unsuitable for germination

of the larger willow species, though some may persist for long periods of time through clonal reproduction. The low-shrub stage can persist for a long time on slopes and well-drained river terraces. Finally, the low-shrub stage is gradually replaced by the very stable niggerhead meadow.

Webber and Walker, 1975

At Prudhoe Bay *Salix lanata* and *Carex aquatilis* are characteristic of stream banks. Other common species include *Dupontia fisheri* and *Saxifraga hirculus*. The *Salix rotundifolia-Chrysanthemum integrifolium-Oxyria digyna* type is found on slumping stream banks.

Wiggins and MacVicar, 1958

Along the gravelly and rocky banks of the major streams with braided drainage patterns, the bars and islands support a few species rarely found in any other habitat in the vicinity of Chandler Lake. Among these are *Salix alaxensis*, *S. glauca*, *Parnassia kotzebuei*, *Bupleurum americanum*, and *Crepis nana*.

Wiggins and Thomas, 1962

Herbs commonly found on gravel and sand bars of major rivers on the Arctic Coastal Plain are:

Crepis nana	*Artemisia trifurcata*
Lupinus arcticus	*Anemone parviflora*
Astragalus spp.	*Cardamine bellidifolia*

Epilobium latifolium
Parnassia kotzebuei
Parrya nudicaulis

Arabis lyrata
Conioselinum cnidiifolium
Bupleurum americanum
Armeria maritima

In the foothills stream banks often provide better protection from wind-driven snow than is afforded in areas of less topographic relief. In such settings Salix richardsonii, Populus balsamifera, and Alnus crispa attain the size of small trees, sometimes reaching a height of 25 ft. Herbaceous plants growing in the willow-alder-poplar thickets include Delphinium brachycentrum, Aconitum delphinifolium, Polemonium boreale, and P. caeruleum.

Strand and supratidal meadow

Britton, 1967

Thinly scattered specimens of Mertensia maritima are often the only plants present on coarse, summer-dry gravels at Barrow, but most of these sites have been badly disturbed by grading and filling. Reindeer were once herded for grazing on gravel areas near Barrow that are now devoid of vegetation.

The coarse sand of a beach crest has a very open cover of Elymus with scattered patches of Taraxacum sp. and Papaver radicatum. Downslope the gravels are considerably mixed with silt, have a thin cover of organic material, and have vegetation consisting of the following species:

willows
Dupontia

Carex ursina
Sagina intermedia

Puccinellia

Cochlearia officinalis

Phippsia algida

Chrysoplenium tetrandrum

Saxifraga rivularis

S. caespitosa

S. cernus

S. foliolosa

Cerastium beeringianum

Mertensia maritima

Distichium flexicaule

Tetraplodon mnioides

Pohlia nutans

P. cruda

Many of these species also grow on gravel flats only slightly above the water level of the lagoons. Puccinellia spp., Saxifraga rivularis, and Cochlearia officinalis are common just above highwater level in intermittent ponds. Dense stands of Carex ursina occur on wet gravels.

Potter, 1972

The shoreline during the summer is subject to large breaking waves carrying a large burden of rolling sand and gravel; washing by ice cold salt water and burial under beach material are unfavorable conditions for plant growth. At any period of the summer the coastline may be subject to the mechanical plowing, shearing, and burial due to ice thrust when the pack ice may be forced many feet above the normal shoreline.

The sand spits which separate the open sea from Walakpa Bay are repeatedly scoured by waves and ice and are, therefore, nearly devoid of vegetation. The shores of Walakpa Bay are protected and support Mertensia maritima, Honckenya peploides, Elymus mollis, and Puccinellia phryganodes. Also common are patches of Cochlearia officinalis, Cerastium beeringianum,

Stellaria humifusa, and *Saxifraga caespitosa*. A prominent coastal bluff forms a sea wall about 25 ft high. This bluff is subject to severe erosion by wave action and from ice-shove across the gently sloping beach. Bare, unstable soil is colonized by *Cochlearia officinalis*, *Taraxacum lyratum*, *Sagina intermedia*, *Oxyria digyna*, *Cerastium beeringianum*, and *Saxifraga rivularis*.

Schamel, 1974

On Egg Island (a small barrier islet near Prudhoe Bay) only four vascular plant species were found:

Honckenya peploides	*Elymus arenarius*
Mertensia maritima	*Puccinellia phryganodes*

Shacklette, 1965b

At Point Barrow beach ridge gravel nearest the water receives sea spray, if not waves, during storms and supports a very limited bryoflora. *Tortula ruralis* is the most abundant bryophyte on these sites, although *Bryum argenteum* and *Ceratodon purpureus* are also present.

Spetzman, 1951

The beach and spit north of Barrow Village lack vegetation near the water on the seaward side, but higher up small patches of *Elymus arenarius*, *Honckenya peploides*, and *Mertensia maritima* occur. On the southeast side of the sand spit bordering Elson Lagoon, slight depressions provide sufficient protection for the development of scattered stands of *Cochlearia*

officinalis, *Ranunculus pygmaeus*, *Saxifraga rivularis* , *S. caespitosa* *Cerastium beeringianum*, *Papaver* sp., and *Draba lactea*.

Spetzman, 1959

A few miles southwest of Barrow, bluffs of silt rise 15 ft above the sea. Actively eroding slopes of silty soil face the sea and border small gullies which dissect the cliff. On these fresh surfaces the following herbs are found:

Juncus biglumis	*Ranunculus pygmaeus*
Oxyria digyna	*Saxifraga rivularis*
Polygonum viviparum	

Wiggins and Thomas, 1962

The plowing and scouring effect of sea ice and the erosive force of breaking waves during violent storms have kept the inner strand practically bare of plant growth. Occasional sheltered spots support small populations of *Mertensia maritima*, *Elymus mollis*, and *Honckenya peploides*. On wider beaches, prostrate mats of several other species occur (listed on p. 16).

Bluffs from 3 to about 65 ft high occur intermittently along the arctic shores of Alaska and present different ecological conditions for plants from those on either the adjacent sandy strands at their feet or on the tundra immediately behind them. These bluffs are subject to deep incision by drainage from the tundra during the spring thaw and thus provide habitats of barren soil and steep slopes. *Saxifraga rivularis* is an important colonizer of such habitats, particularly along gullies where

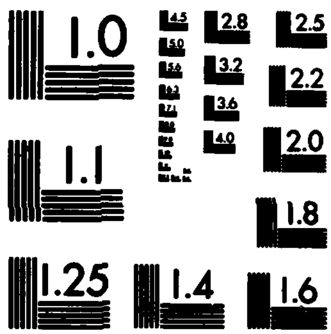
AD-A120 573 A LITERATURE SURVEY ON THE WETLAND VEGETATION OF ALASKA 3/3
(U) ALASKA UNIV FAIRBANKS INST OF ARCTIC BIOLOGY AND
MUSEUM A R BATTEN ET AL. AUG 82 WES-TR-Y-82-2

UNCLASSIFIED DACW39-76-M-2473 F/G 8/6 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

some solifluction and slumping occurs. *Cochlearia officinalis* often grows in rank, dense patches at the bases of such bluffs.

Saline or brackish marsh

Koranda and Evans, 1975

Salt flats are vegetated by halophytic grasses and herbs.

Potter, 1972

Hippuris tetraphylla occurs in brackish water along the shoreline of coastal bays.

Spetzman, 1951, 1959

Larger depressions on the southeast side of the sandpit bordering Elson Lagoon provide shelter from winds and support a grassy community of *Alopecurus alpinus*, *Arctophila fulva*, and *Dupontia fisheri* with lesser amounts of *Poa arctica*, *Calamagrostis neglecta*, *Puccinellia paupercula*, *Salix pulchra*, and *Potentilla hyparctica*.

Weller, 1976

At Storkersen Point brackish or subsaline ponds and lagoons are vegetated by *Puccinellia phryganodes* and *Carex subspathacea*.

Vegetation maps

Vegetation maps of the following areas are found in Spetzman (1951):

Point Barrow (figure 3, p. 39)

Alatak (figure 4, p. 43)

Lake Noluck (figure 5, p. 45)

Umiat (figure 6, p. 50)

Anaktuvuk Pass (figure 7, p. 54)

Spetzman (1959) presented the following vegetation maps:

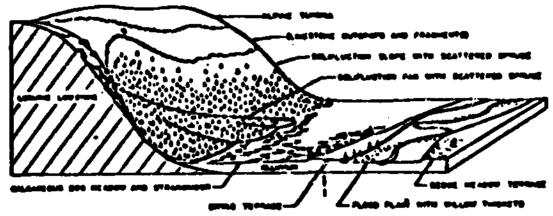
Point Barrow (figure 6, p. 31)

Noluck Lake (figure 7, p. 34)

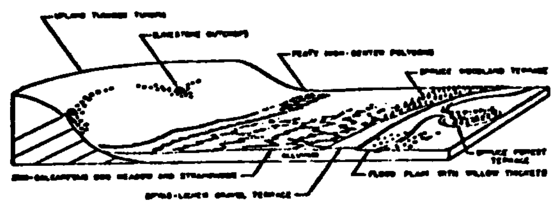
Anaktuvuk Pass (figure 8, p. 38)

Walker and Webber (1973) have prepared a draft vegetation map of the IBP study area at Barrow, and Webber and Walker (1975) presented soils and vegetation maps of the Tundra Biome study area at Prudhoe Bay (plate I, in pocket on back cover).

Webber and Walker (1975) have also prepared a schematic representation of the Prudhoe Bay terrain showing the topographic and spatial interrelations of vegetation types (figure 1, p. 82-83).



a. South-facing slope



b. North-facing slope

Figure 14. Diagram showing the major landscape units of the upper Firth River valley. (From Drew and Shanks, 1965, figures 2 and 3, p. 287.)

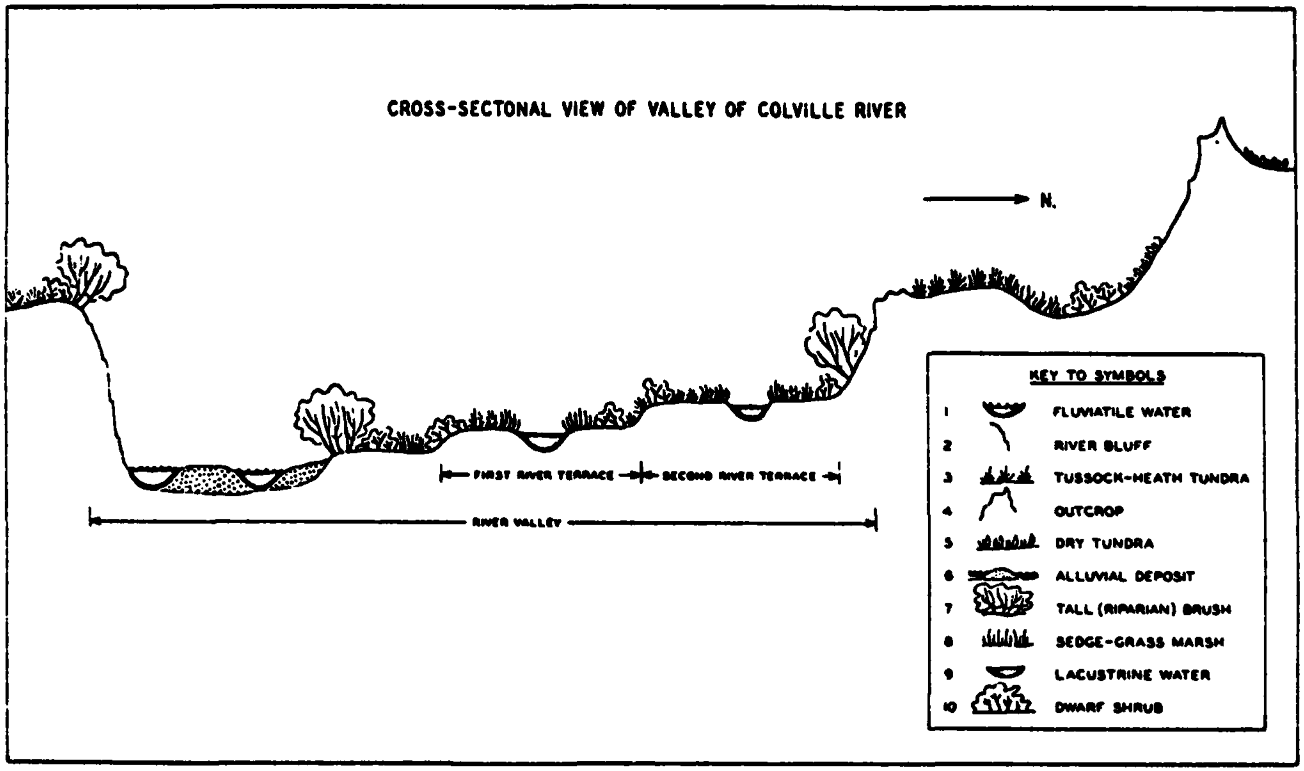


Figure 15. Cross-sectional diagram of the valley of the Colville River and adjacent uplands in the vicinity of Umiat, Alaska, showing the relationship between the principal habitat types and topography. (From Kessel and Cade, 1958, figure 4, p. 12.)

INTERIOR ALASKA

This region contains a complex of lowlands, uplands, and rugged mountains. Lowlands in this region include the Copper River, Northway-Tanacross, Tanana-Kuskokwim, Holitna, Innoko, Tozitna-Melozitna, Nowitna, and Buckland River lowlands; the Koyukuk, Kanuti, and Yukon flats; and most of the Susitna Valley. The remainder of the region consists of undulating uplands, rounded but rugged mountains, and the sharp peaks and ridges of the Alaska Range and the St. Elias and Wrangell mountains. Major rivers include the Kuskokwim, Copper, Susitna, and the Yukon and its major tributaries, the Koyukuk, Tanana, and Porcupine. Thaw and oxbow lakes abound in the lowlands and moraine-dammed lakes are found in the mountains. During the Pleistocene, large glaciers extended south from the Brooks Range and north and south from the Alaska Range, completely covering all of Alaska south of the Alaska Range. However, most of the terrain between the Brooks Range and the Alaska Range was not glaciated, except for scattered small glaciers in isolated mountainous areas (Wahrhaftig, 1965). Continuous permafrost is found in the northern and western parts of this region, and discontinuous permafrost prevails over most of the remainder, except for small localities where permafrost is only sporadic (Viereck and Little, 1975). In the area with discontinuous permafrost, permafrost is usually present on north slopes and poorly drained lowlands but is usually lacking on south slopes and well-drained alluvium.

The climate is continental with warm, dry summers and cold, dry winters. Seasonal temperature fluctuations are greatest on the Yukon Flats

where the average July maximum is 76° F and the average January minimum is -28° F. The average annual temperature of the region ranges from 30° F in the southwest to 15° F in the northeast. Average annual precipitation varies from 80 inches in the high mountains in the south to less than 10 inches on the Yukon Flats (Viereck and Little, 1975).

The vegetation is predominantly forest, though treeless areas are common. A closed spruce-hardwood forest of white spruce (*Picea glauca*), black spruce (*Picea mariana*), paper birch (*Betula papyrifera*), aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*) occurs on moderately to well drained sites, including south slopes, alluvium, and burned areas. Open low-growing forests of black spruce, sometimes interspersed with tamarack (*Larix laricina*), paper birch, and willows,are found on poorly drained sites, commonly the north slopes and lowlands. Very poorly drained parts of lowlands support treeless bogs, though widely spaced black spruce and tamarack may be present (Viereck and Little, 1972). Tundra vegetation is found above timberline and varies from widely spaced mats of plants on windswept ridges, to lush growths of grasses and sedges in sheltered valleys, to shrub-choked ravines on steep slopes. Considerable areas of unvegetated ice and bare rock are found in the high mountains.

References to Interior Alaskan Wetlands

Dacknowski-Stokes, A. P. 1941. Peat resources in Alaska. U.S. Dept. Agr. Tech. Bull. No. 769. 84 p.

Drury, W. H., Jr. 1956. Bog flats and physiographic processes in the upper Kuskokwim River region, Alaska. Harvard Univ. Contrib. Gray Herb. 178. 130 p.

Hakala, John B. 1952. The life history and general ecology of the beaver (Castor canadensis Kuhl) in interior Alaska. Univ. of Alaska M.S. thesis. 181 p.

Hanson, Herbert C. 1950. Vegetation and soil profiles in some solifluction and mound areas in Alaska. Ecology 31:606-630.

Hanson, Herbert C. 1951. Characteristics of some grassland, marsh, and other plant communities in western Alaska. Ecol. Monogr. 21:317-378.

Hanson, Herbert C. 1958. Analysis of Nelchina Caribou Range. U.S. Dept. Int. Fish and Wildlife Service, Federal Aid in Wildlife, Job Completion Report, Job 6, W-3-R-12, Juneau, Alaska. 68 p.

Heilman, Paul E. 1966. Change in distribution and availability of nitrogen with forest succession in interior Alaska. Ecology 47:825-831.

Johnson, P. L. and T. C. Vogel. 1966. Vegetation of the Yukon Flats region, Alaska. U.S. Army Materiel Command, Cold Regions Research and Engineering Lab. Research Report 209. 53 p.

Kessel, Brina and George B. Schaller. 1960. Birds of the upper Sheenjek Valley, Northeastern Alaska. Biol. Pap. Univ. Alaska No. 4. 59 p.

Lutz, H. J. and A. P. Caporaso. 1958. Indicators of forest land classes in air-photo interpretation of the Alaska interior. U.S. For. Serv., Alaska For. Res. Cent. Stn. Pap. 10. 31 p.

Porsild, A. E. 1939. Contributions to the flora of Alaska. Rhodora 41:141-301.

Scott, Richard W. 1972. Ecology and phytogeography of alpine vegetation in the southeastern Wrangell Mountains, Alaska. Univ. of Michigan Ph.D. thesis. 314 p.

Scott, Richard W. 1974b. Alpine plant communities of the southeastern Wrangell Mountains, Alaska, p. 284-306. In Bushnell, V. C. and M. G. Marcus, eds., Icefield Ranges Research Project, Scientific Results: Vol 4. Am. Geogr. Soc.

Viereck, Leslie A. 1962. Alaska Wildlife Investigations, Sheep and Goat Investigations, Range Survey. Job Completion Report, Research Project Segment, Federal Aid in Wildlife Restoration. Project No. W-6-R-3, Work plan E, Job No. 2-a. 21 p.

Viereck, Leslie A. 1963. Alaska Wildlife Investigations, Sheep Investigations, Survey of Range Ecology. Work Plan Segment Report, Federal Aid in Wildlife Restoration. Project No. W-6-R-4, Work plan E, Job No. 2-a.

Viereck, Leslie A. 1970. Soil temperatures in river bottom stands in interior Alaska, p. 223-233. In Ecology of the Subarctic Regions, Proceedings of the Helsinki Symposium. UNESCO.

Viereck, Leslie A. 1973a. Wildfire in the taiga of Alaska. Quaternary Research 3:465-495.

Viereck, Leslie A. 1973b. Ecological effects of river flooding and forest fires on permafrost in the taiga of Alaska, p. 60-67. In Permafrost: The North American Contribution of the Second International Conference. Nat. Acad. Sci., Washington, D.C.

Viereck, Leslie A. and Elbert L. Little. 1972. Alaska trees and shrubs. U.S. Dept. Agr., Forest Service, Agricultural Handbook No. 410. 265 p.

Williamson, Francis S. L. and Leonard J. Peyton. 1962. Faunal relationships of birds in the Iliamna Lake area, Alaska. *Biol. Pap. Univ. Alaska* No. 5. 73 p.

Pond and lake

Drury, 1956

Fresh water beach vegetation is found on silt shores where there is gradual lowering of the ground-water table or filling by river-borne silt. Such pond shores are characteristic of the deciduous and white spruce-mixed forests on the young floodplain surface of the upper Kuskokwim. Most of the ponds are old oxbows but many exist in dune hollows and similar depressions on terrace surfaces. Three zones of vegetation are found in and around these ponds: 1) shallow water vegetation, essentially floating; 2) shallow water vegetation, emergent; and 3) wet shores.

Johnson and Vogel, 1966

Lakes and quiet waterways on the Yukon Flats may contain *Nuphar polysepalum*. [Diagram of a transect through zones of shoreline vegetation are reproduced here as figures 16 and 17.]

Porsild, 1939

Aquatic plants in small ponds in Goldstream Valley include *Potamogeton pusillus*, *P. tenuifolius*, *P. porsildiorum*, *Ranunculus purshii*, and *Callitriche verna*.

Williamson and Peyton, 1962

The lacustrine waters type includes Iliamna Lake and the numerous lakes occurring on the tundra and in the wooded areas. All of these are essentially free of vegetation; emergent plants may or may not be prominent

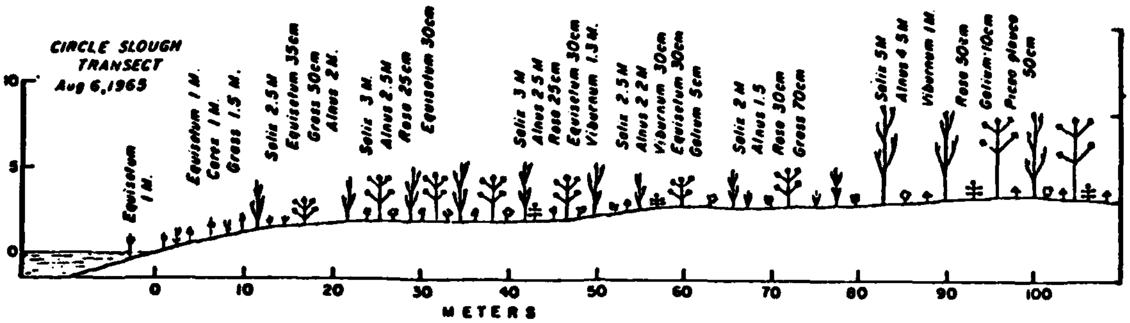


Figure 16. Diagram of a transect through zones of riparian succession along a slough near Circle City. (From Johnson and Vogel, 1966, figure 33, p. 44.)

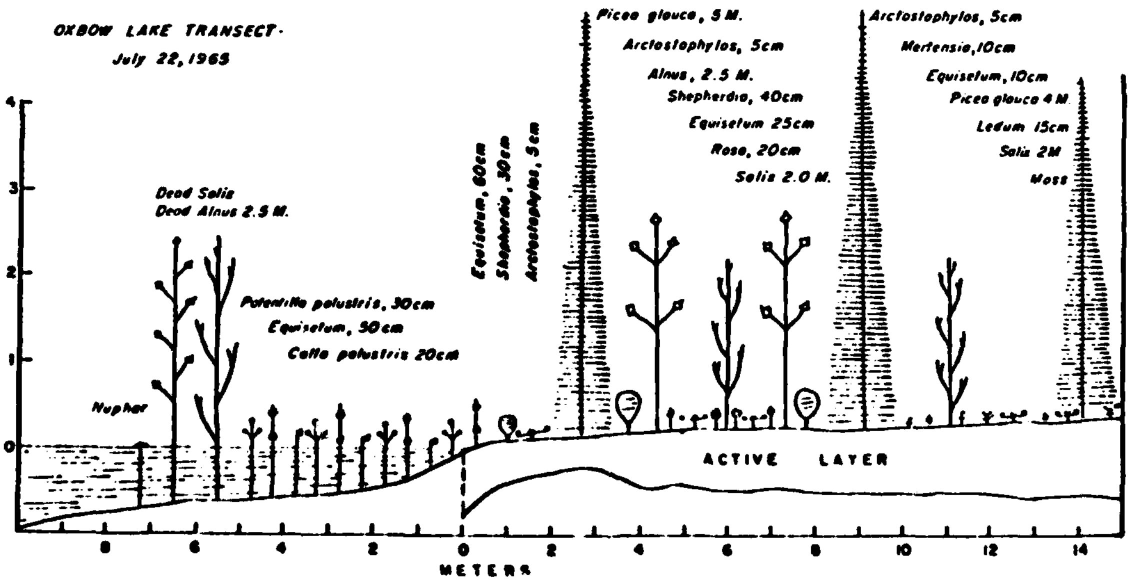


Figure 17. Diagram of a transect through zones of shoreline vegetation on an oxbow lake near Circle City. (From Johnson and Vogel, 1966, figure 34, p. 44.)

along the shore lines. Not included here are the many small ponds of the wet tundra or the fresh water marsh.

Fresh water marsh

Hanson, 1950

Chief species of an alpine sedge type at Eagle Summit are *Carex bigelowii*, *C. membranacea*, *Eriophorum vaginatum*, and mosses. The stand studied is on a slope of 5° to 10° at an elevation of 3880 ft. The soil is saturated and solifluction is indicated by the hummocky surfaces and by terraces. The soil consists of a 7-inch layer of peat overlying gray silt and gravel. There is a pronounced horizontal cleavage plane between the peat and the mineral soil, and frozen ground was encountered at a depth of 24 inches.

Another alpine sedge stand at Sable Pass in Mt. McKinley National Park (3900 ft) is dominated by *Carex bigelowii* which far exceeds all other species in cover and frequency. *Salix polaris* and *Equisetum arvense* are also common. Solifluction is indicated by wave-like terraces. The soil is a very dense, tough sod overlying silt. The ground was frozen at a depth of 46 inches.

Hanson, 1951

A *Carex aquatilis* stand (stand 84, p. 366) at Polychrome Pass on level ground at 3600 ft contains, in addition to the sedge, *Equisetum alaskanum*, *Salix pulchra*, and mosses. The soil is alternating layers of sandy silt and impervious clay above an impervious layer of clay at a depth of 24 inches.

Hanson, 1958

One of the three subtypes of the dwarf heath shrub vegetation type occupies poorly drained soils on gentle slopes (5° or less). Dominant species are Vaccinium uliginosum, Empetrum nigrum, Ledum decumbens, Vaccinium vitis-idaea, Cassiope tetragona, Arctostaphylos alpina, and Carex bigelowii. These sites are subject to solifluction and frost action, and a polygonal pattern is evident. The soil consists of 2 to 3 inches of organic material overlying silt. Seepage begins at a depth of 10 inches, and standing water is often present in the depressions between polygons.

A Salix pulchra community occurs on hummocky surfaces with scattered frost boils. The soil is very wet and consists of 4 inches of organic-rich loam overlying a gravelly loam. Species associated with the dominant Salix pulchra are Artemisia arctica, Rubus arcticus, Carex bigelowii, Festuca altaica, and Sedum roseum. Mosses are very abundant.

The sedge type is a marsh that is widely distributed along ponds, lakes, and streams. It is extensive in recently filled lake and pond beds. Usually lichens are not present.

Johnson and Vogel, 1966

In the Yukon Flats, sedges, particularly Carex aquatilis and Equisetum arvense, are prevalent as emergents along lakes and quiet waterways.

Kessel and Schaller, 1960

In the Sheenjek Valley, sedge-grass marsh occurs on wet sites, often near the outlets or inlets of ponds. Water may be 10 to 12 inches deep in

these areas. The vegetation is dominated by species of *Carex* and *Eriophorum*; *Carex aquatilis* is typically abundant.

Tussock-heath tundra is found in areas that are moist, but seldom with standing water, on flats near ponds and streams, and in draws and pockets at higher altitudes. It often shows a polygonal pattern of relatively flat, moist areas separated by considerably dryer ridges a foot or so high. In these patterned sites the vegetation of the wettest area is dominated by *Drepanocladus* sp., *Equisetum* sp., and *Carex* spp.

Scott, 1972

Five plant associations grow in wet or periodically flooded habitats on mineral soils. 1) The *Carex bigelowii-Aulacomnium palustre* association is widespread and common in the middle alpine zone from 4890 to 5350 ft in the southeastern Wrangell Mountains. It is typical on relatively well-irrigated benches and moderate south- and west-facing slopes. On Frederika Valley slopes it is characteristic of seasonally wet seepage areas below snowdrifts. Typical species, in addition to those named above, include *Drepanocladus intermedius*, *Pedicularis capitata*, *Peltigera malacea*, *Petasites frigidus*, *Polygonum bistorta*, and *Tomenthypnum nitens*.

2) The *Carex aquatilis-Equisetum arvense* association is occasional in the Chitistone-Skolai region and occurs only in lowland wet areas. It is found on fine-grained regosols of braided floodplains and alluvial fans. The soil organic layer is thin or lacking and no evidence of gleying was noted. Soil characteristics, plus a paucity of species,indicate that the association is an early successional stage in wet meadow development. Typical

vascular species in addition to those named are Epilobium angustifolium, Equisetum variegatum, and Juncus arcticus.

3) The Carex lachenalii-Oxyria digyna association is found in snow-beds. These sites have a short growing season and are usually well irrigated by meltwater. Frost action is intense and results in a discontinuous vegetation mat. Soils vary from azonal lithosols to brown tundra soil under vegetation mats. Typical species other than those named include Claytonia sarmentosa, Poa arctica, and Saxifraga punctata.

4) The Salix polaris-Hylocomium alaskanum association occurs in wet seepage channels and margins of rivulets in upper portions of the middle alpine zone. Soils vary from lithosols to shallow zonal (15 cm) with a thin organic horizon. Other common species are Antennaria monocephala, Artemisia arctica, Aulacomnium palustre, Cladonia pyxidata, Peltigera malacea, Poa arctica, and Stereocaulon alpinum.

5) The Arctagrostis latifolia-Equisetum arvense association is widely distributed throughout the middle alpine zone and is typical of moist swales. In addition to the named species, common species are Artemisia arctica, Carex podocarpa, Mertensia paniculata, Petasites frigidus, Polemonium acutiflorum, and Valeriana capitata. Meadow tundra soils are typical of these sites.

Viereck, 1962

Where snow accumulation is deep in the winter and melt occurs late in spring or summer, snow-bed communities are found. Vegetation that occupies these sites varies with the time that the snow melts in the summer and with

slope, exposure, altitude, and parent material. There is, therefore, no one characteristic plant community that can be considered as a typical snow-bed community. Even within one snowbank area the vegetation usually forms conspicuous bands related to the time that the area first becomes free of snow.

Viereck, 1963

The sedge meadow type occurs in high basins of the Alaska Range where the snow remains until early summer and where the soils remain wet most or all of the summer. In the wetter areas the sedge mat consists primarily of *Eriophorum angustifolium* while in the slightly drier sites *Carex bigelowii* forms the dominant cover. Mosses are common throughout the sedge mat and low shrubs of *Salix pulchra* occur occasionally. In some areas tussocks of *Eriophorum vaginatum* are found.

Williamson and Peyton, 1962

The fresh water marsh type at Iliamna Lake is very much restricted in extent. The lush emergent vegetation consists of species of *Carex*, *Equisetum*, and grasses.

Peatland

Dachnowski-Stokes, 1941

A muskeg occupying a depression in glacial material a few hundred feet above the Chulitna River is vegetated by scattered stunted black

spruce (Picea mariana), Betula glandulosa, Ledum groenlandicum, Andromeda polifolia, Kalmia glauca, Potentilla fruticosa, Vaccinium uliginosum, Sphagnum spp., and sedge tussocks. The peat consists of a thin 3- to 4-inch layer of Sphagnum peat overlying 6 to 7 ft of sedge peat above 2 to 5 feet of Hypnum peat. This is taken to indicate that this particular muskeg started out as a flooded basin with floating mats of mosses (Hypnaceae) and pond weeds, later supported sedges and some trees, and only recently has been invaded by Sphagnum.

At Broad Pass grasses and sedges are relatively more abundant in wetter portions of the muskegs, otherwise they are floristically similar to others further south.

A large (400-acre) muskeg near Fairbanks is vegetated with scattered black spruce, tamarack (Larix laricina), and abundant Sphagnum mosses (S. medium, S. fuscum, S. rubrum, and others) which form hummocks about 1.5 ft above the intervening hollows. Sedges are prominent in the marginal portions of this muskeg, and eriacaceous shrubs occupy the Sphagnum hummocks near the center. The peat consists of a 3-ft layer of Sphagnum moss peat over a 1-ft layer of woody sedge peat over a 2-ft layer of moss and sedge peat.

Drury, 1956

In the upper Kuskokwim region peat bogs form in three general ways:

1) Colonization of a body of water by peat-forming plants. The first colonizers are immersed aquatic mosses (Sphagnum, Calliergon, and Drepanocladus). These form mats which eventually support growths of sedges; these weave the

mats tighter and contribute dead parts to the system, eventually filling the basin and leading to the establishment of a quaking (topogenous) bog.

2) Invasion of lowlands by swamp-forming vegetation. Mosses colonize depressions and hold the moisture. This causes the local water table to rise and enables the mosses to spread, gradually occupying more of the forest floor until the sodden conditions kill off the forest and a shallow bog is formed (paludification).

3) Local thawing of perennially frozen ground. Thawing of this material results in subsidence to considerable depths, 15 ft in some examples. Thawing of permafrost can be initiated by any break in or loss of effectiveness of the insulating moss cover. This can be caused by fires, blow-downs, bursting of frost-built hummocks, well-used game trails, or by water that collects in Sphagnum mosses invading the forest by the swamping process. Once a break is started, slumping of the thawed material exposes more frozen ground to the warmth of the sun or to contact with water, and the original depression rapidly expands. Thawing expands from neighboring centers of origin to coalesce, and the result is a large area of anastomosing bogs with isolated islands or peninsulas of the former floodplain surface. [An idealized cross section of the floodplain of the upper Kuskokwim River is reproduced here as figure 18.]

As soon as a body of water is colonized by bog vegetation, the slow accumulation of organic remains begins to fill the basin. Changes in water level or in frost activity in the bog can, however, reverse the direction of this modification and return the area to open bog or shallow water. Plant remains accumulate, mixed with silt deposited in the bogs by winds or

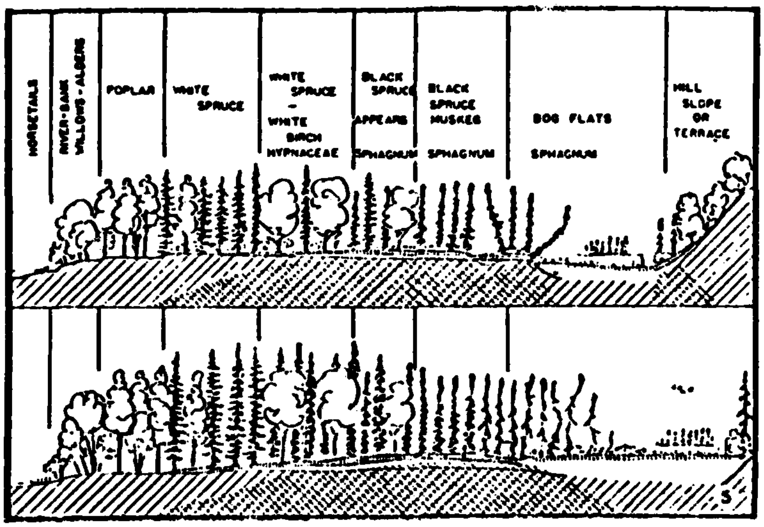


Figure 18. Idealized cross section of the upper Kuskokwim River floodplain. The upper diagram represents areas where bogs have formed by thawing, the lower, areas where bogs have formed coincident with a rise of water table and swamping. Vertical hatching is living mosses; white areas are peat accumulations; diagonally hatched areas (top right to bottom left) are sediments; diagonally hatched areas (top left to bottom right) are permafrost. (From Drury, 1956, figure 5, p. 15.)

by water, and eventually allow colonization by progressively less hydrophytic vegetation. Woodland Sphagna, heaths, dwarf birches, and finally black spruce, larch, or mixed forest appear on consolidated deposits of peat and silt. Increased compaction of the peat reduces the flow of bog waters which would otherwise tend to unify its temperature. As water no longer percolates freely, perennially frozen ground is formed. Discrete ice lenses form in the deposit increasing the volume of peat and silt. The result of all these processes is to raise the level of the forest floor. The drier and more stable conditions thus produced are usually marked by expansion of the forest and extensive growth of lichens until the vegetation is similar to that originally destroyed by paludification. The advance of bogs into the frozen alluvium by thawing can occur simultaneously with the filling of sodden depressions by organics. The two antagonistic processes form a cycle which is presently active and which has had wide-reaching effects on the sediments of the lowlands throughout the past. [This cycle is diagrammed here in figure 19.]

Conspicuous development of Carex communities indicates a significant soligenous element to the bogs. The soligenous water includes mineral elements not usually found in the rainfall collecting on the surface.

Peat bog vegetation is described under three headings: 1) areas of relatively consistent simple stands; 2) areas of anastomosing bog ridges and intervening bog hollows; and 3) areas where raised peat ridges form beaches along the edges of ponds and lakes.

Consistently simple stands fall into three aspect types: a) vegetation meadow-like, includes moats, bog hollows, sedge meadows, and Scirpus-Myrica

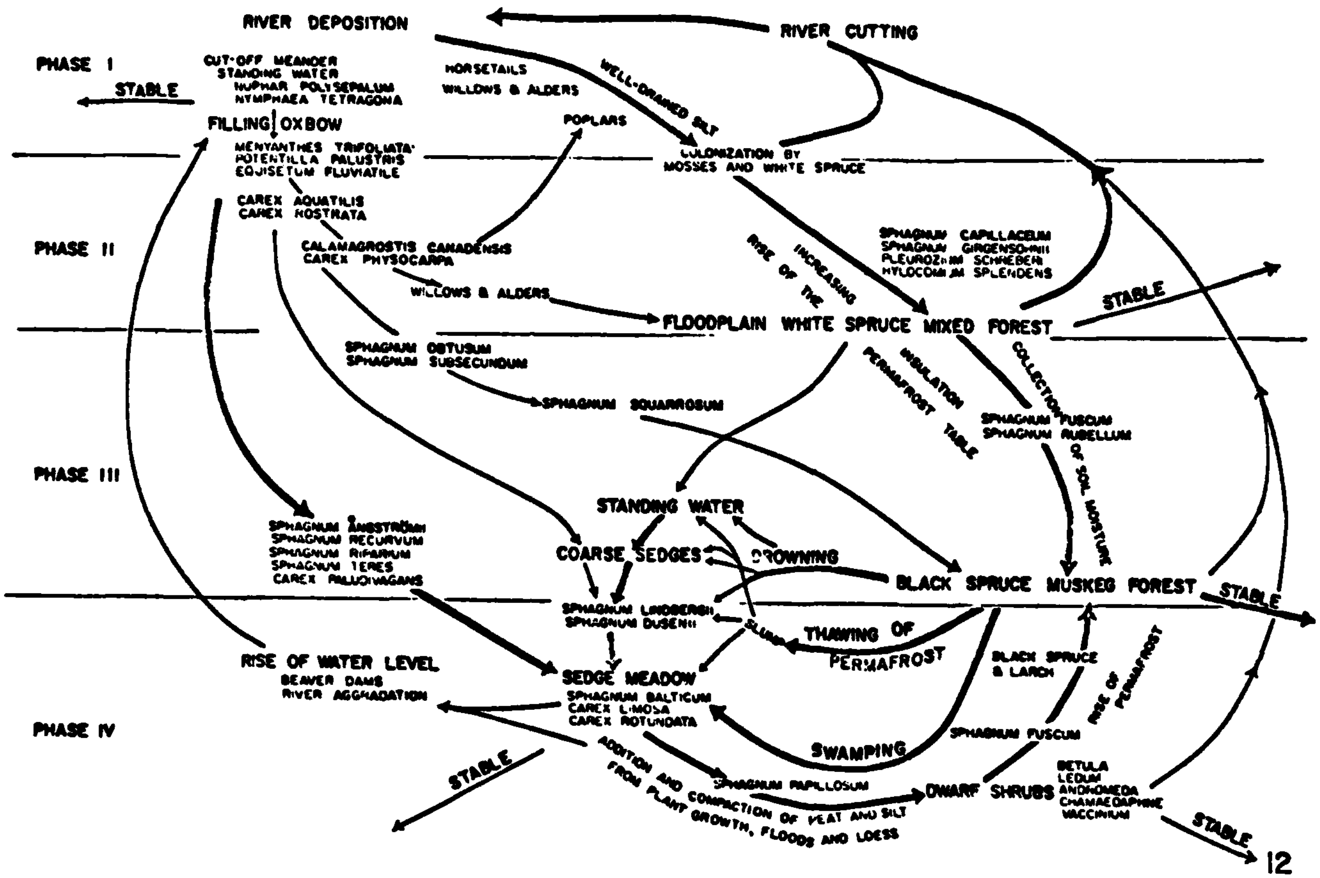


Figure 19. Flow diagram of vegetation and physiographic processes on the upper Kiskokwim River floodplain. This diagram emphasizes the coordination of changes of vegetation and of underlying alluvial sediments. The size of letters is an indication of the relative conspicuousness or area occupied by the various vegetation types, and the breadth of arrows indicates how widespread the changes are. As indicated, several of the vegetation types maintain stability until their site conditions are altered by physiographic processes. This emphasizes the point that the changes indicated are not unidirectional with the age of the floodplain. (From Drury, 1956, figure 12, p. 31.)

areas; b) vegetation low heaths and dwarf birch shrubs, not more than 6 inches high; and c) vegetation of tall shrubs about 4 ft high. These types may have a moss carpet or a mud substrate; in either case the bottom may be firm or yielding but generally firmer where there are shrubs.

The areas of patterns of anastomosing bog ridges and intervening bog hollows are usually found away from central bodies of water. There are two parts of the pattern, the bog ridges and bog hollows. The bog ridges may form into a net-like pattern or festoons, parallel ridges like waves in the wettest parts. The more mesophytic species of *Sphagnum*, sedges, and heaths occupy the ridges, the more hydrophytic ones the hollows. There is a sharp segregation of species involved, and only rarely is the vegetation pattern the result of only differential species abundance.

Raised peat ridges that form beaches along the edge of ponds and lakes present a telescoped transect of the wet to dry sites. The ridges are caused by wind-driven waves pounding against the edge of the pliable bog carpet or by forces generated by the drifting of ice in spring.

Vegetation influenced less by the water table than by the combined influence of silt and peat develops when ponds with shelving silt shores are invaded by peat-forming vegetation that clogs the outlets and impedes the drainage system. These ponds support vegetation largely characteristic of peat bogs but also traces of the original vegetation established on a silt shoreline. [A summary of the vegetation associations on the upper Kuskokwim floodplain and their ecological relationships is reproduced here in figure 20.]

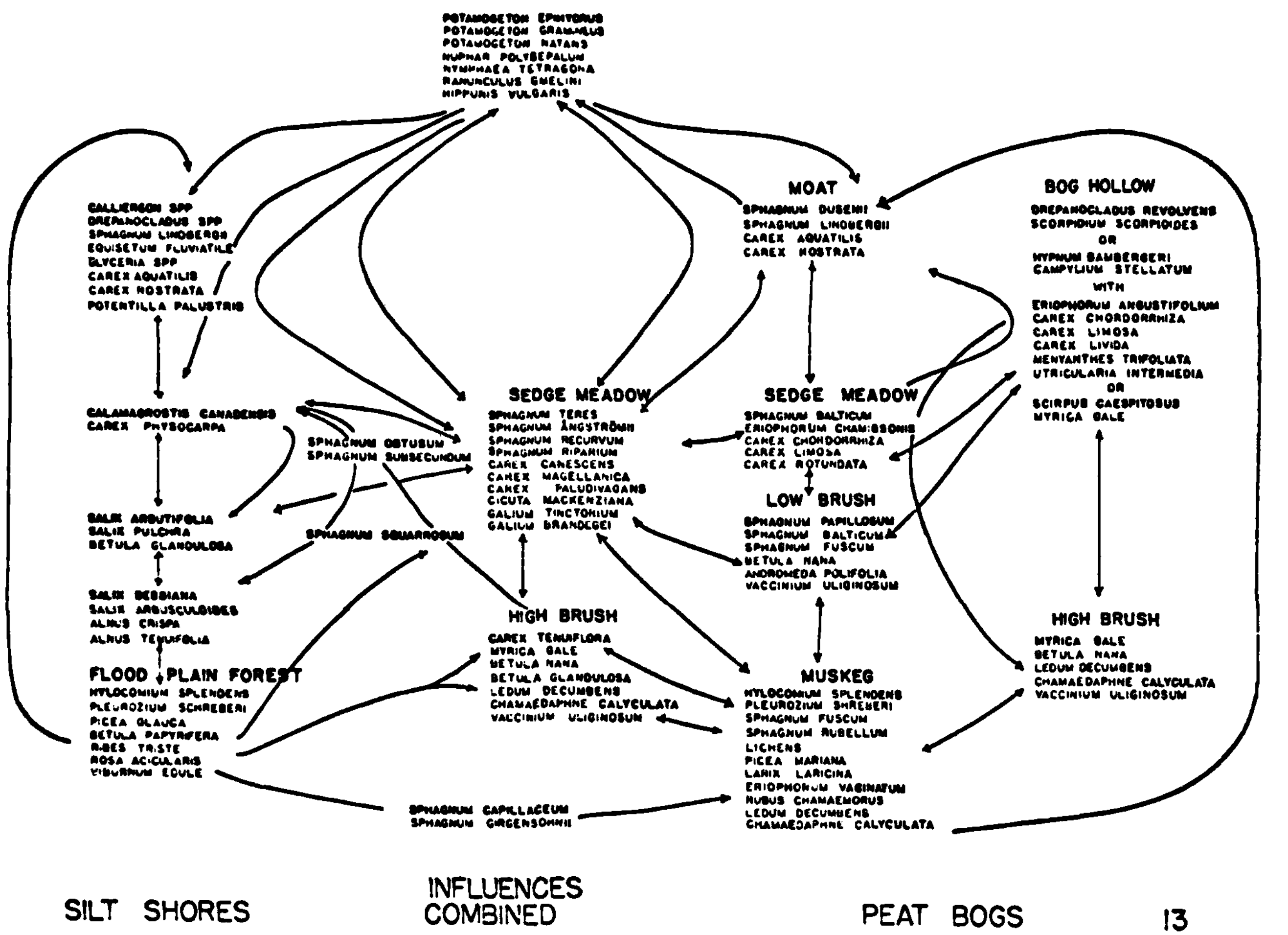


Figure 20. Vegetation associations on the upper Kuskokwim River floodplain. Associations of plants together that have been found consistently in the field are represented in sequence from wet to dry sites. There is no unidirectional development although on first examination the vertical columns seem to indicate such a tendency. (From Drury, 1956, figure 13, p. 37.)

Hakala, 1952

The vegetation of muskegs in the Fairbanks area is composed of many grasses, sedges, heaths, and low brush with scattered patches of black spruce and tamarack. The substrate is usually frozen at a depth of 2 ft or less. Common species include:

Chamaedaphne calyculata	Eriophorum callitrix
Andromeda polifolia	Carex spp.
Ledum groenlandicum	Calamagrostis sp.
Rubus chamaemorus	Poa sp.

Hanson, 1950

Scattered throughout a sedge-heath-Sphagnum bog are tussocks formed chiefly by the growth of Eriophorum vaginatum. Pleurozium schreberi, Hylocomium splendens, and living Sphagnum extend about 3 inches above the dead Sphagnum and other mosses on the hummocks. Lichens form a loose layer on top of and between the Eriophorum stems. Carex bigelowii, though providing less cover than the Eriophorum, is similar in frequency. Other important species are Ledum decumbens, Vaccinium uliginosum, V. vitis-idaea, V. ooxycoccus, Empetrum nigrum, Andromeda polifolia, and Betula nana. The peat underlying this vegetation is at least as deep as the thawed layer, which was 26 inches.

Near Healy a sedge-heath-Sphagnum bog is undergoing solifluction on a north-facing slope of about 5° at an elevation of 2600 ft. Important species are Sphagnum, Carex bigelowii, Ledum decumbens, Betula nana, and Vaccinium uliginosum. The substrate consists of 8 to 12 inches of living

Sphagnum overlying 5 inches of peat over a sticky fine silt. Frozen ground was encountered 10 inches below the base of the living Sphagnum.

Hanson, 1951

A Calamagrostis neglecta-Carex physocarpa-C. aquatilis community occurs in a small basin on a bench at an elevation of about 1800 ft near Healy. Eriophorum angustifolium is also conspicuous. A 12- to 15-inch-thick moss layer covers a 9-inch layer of peat. Both the moss and the peat are saturated with water.

Hanson, 1958

The bog type is characterized by Sphagnum spp., Andromeda polifolia, Oxycoccus, Rubus chamaemorus, Carex spp., and Eriophorum spp. Lichens are usually not well developed.

Ponds and lakes are filled in by the invasion of water lilies, followed by sedge borders and sedge-grass marshes. Sphagnum and other mosses form hummocks; Rubus chamaemorus and heath shrubs invade these hummocks. The hummocks enlarge and coalesce and black spruce becomes established. Lichens accompany the dwarf heath shrubs and spruce.

Heilman, 1966

Five types of vegetation grow on north-facing slopes: 1) birch-alder; 2) birch-alder with understory of black spruce; 3) black spruce-mosses (no Sphagnum species); 4) black spruce-Sphagnum; and 5) Sphagnum-black spruce. In general, these form a secondary successional sequence following

fire or other disturbance on north slopes. The black spruce-mosses type is well adapted to fire and will regenerate itself quickly after light burning. Fires in the two types with Sphagnum and severe fires in the black spruce-mosses type usually result in succession by the birch-alder type.

In Interior Alaska the development of Sphagnum bogs on sites formerly occupied by productive forest is a process of gradual deterioration of site associated with the accumulation of moss layers on the forest floor. Succession is accompanied by an increasing nitrogen deficiency. Black spruce growing on the Sphagnum bogs are extremely nitrogen deficient. As the moss layers thicken, the soils become increasingly cold with permafrost rising to within as little as 15 inches of the surface of the Sphagnum soils. Examination of the distribution of nitrogen revealed very small quantities of nitrogen in the upper and warmer portions of the soil profiles with the bulk of the nitrogen located in the very cold lower layers. In contrast, soils under birch have most of the nitrogen located in the warmest upper layers. Burning, although changing many factors including volatilization of an undetermined amount of nitrogen, may lead to a large increase in available nitrogen because of the change in distribution of the nitrogen in the soil.

Johnson and Vogel, 1966

Bog species dominate extensive areas of muskeg with or without scattered black spruce, particularly on older floodplains no longer subject to flooding. Mosses, lichens, and liverworts are abundant on these sites.

Sphagnum species are locally common but seldom dominant. Abrupt hummocks or sinuous peaty ridges often rise a meter above the surrounding bog surface and represent ice-cored palsen. Strangmoor is not conspicuous on the Yukon Flats.

Bog species tend to segregate along a moisture gradient. [One set of observations north of Circle City is diagrammed in figure 21.] The muskeg is dominated by black spruce, eriacaceous shrubs and dwarf birch, lichens, and Sphagnum moss. The sequence should be not interpreted as developmental. [A diagram showing generalized vegetation types along a topographic gradient in Interior Alaska is reproduced as figure 22.]

Scott, 1972

Two plant associations are found on wet soils in which varying amounts of organic matter have accumulated.

1) The Carex aquatilis-Aulacomnium palustre association is found in wetlands of the Skolai River valley, Southeastern Wrangell Mountains. This association occupies old surfaces with well-developed meadow or half-bog soils.

2) The Petasites frigidus-Aulacomnium palustre association is widely distributed throughout the study area from the lower alpine to the upper limits of the middle alpine zone, and is characteristic of well-irrigated slopes and level areas with standing water. Soils vary from wet alpine meadow to half-bog. Common species, in addition to those named, include Anemone richardsonii, Equisetum scirpoides, Hylocomium alaskanum, Polemonium

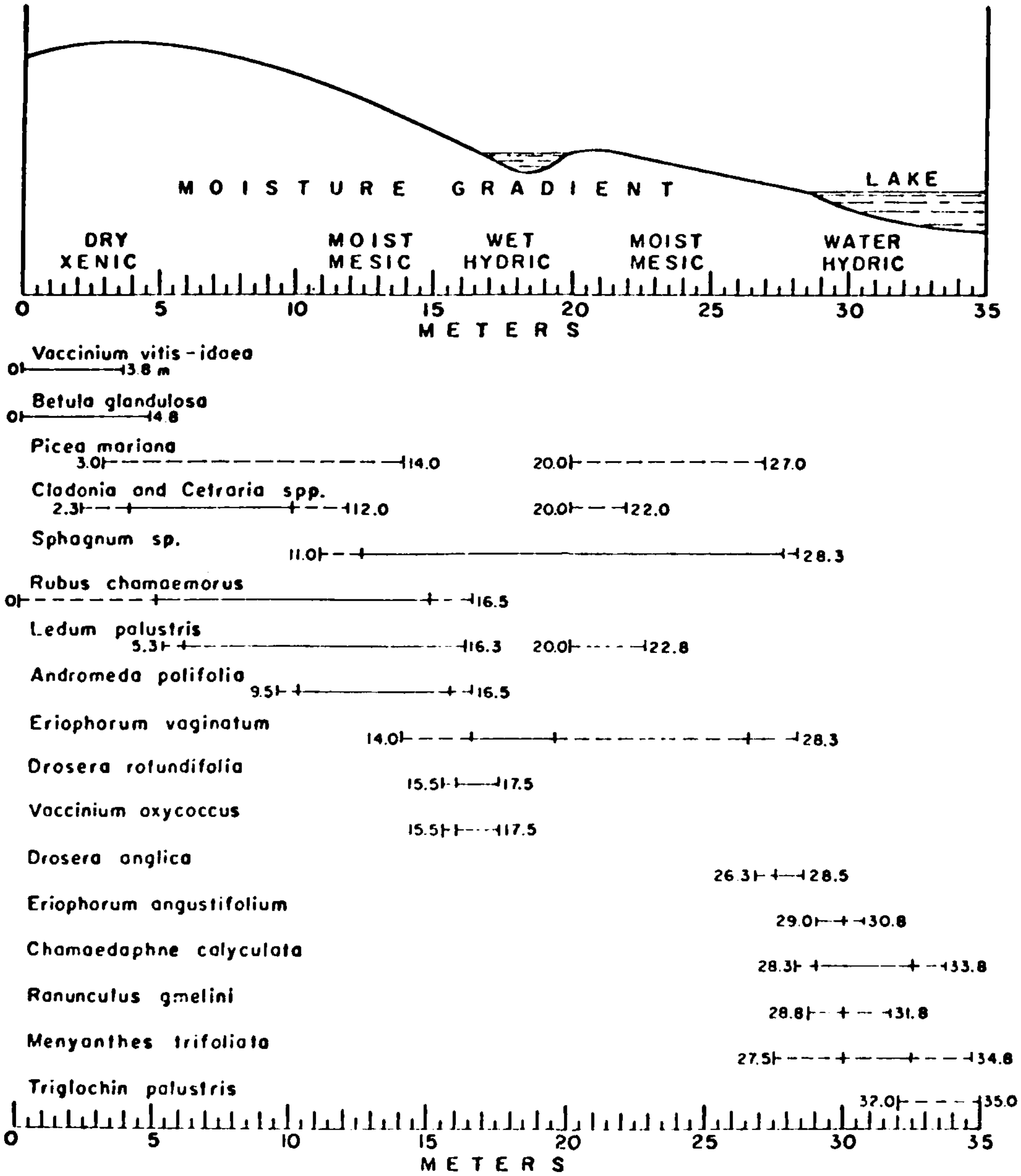


Figure 21. Distribution of bog species along a moisture gradient. Data obtained near Circle City. (From Johnson and Vogel, 1966, figure 35, p. 46.)

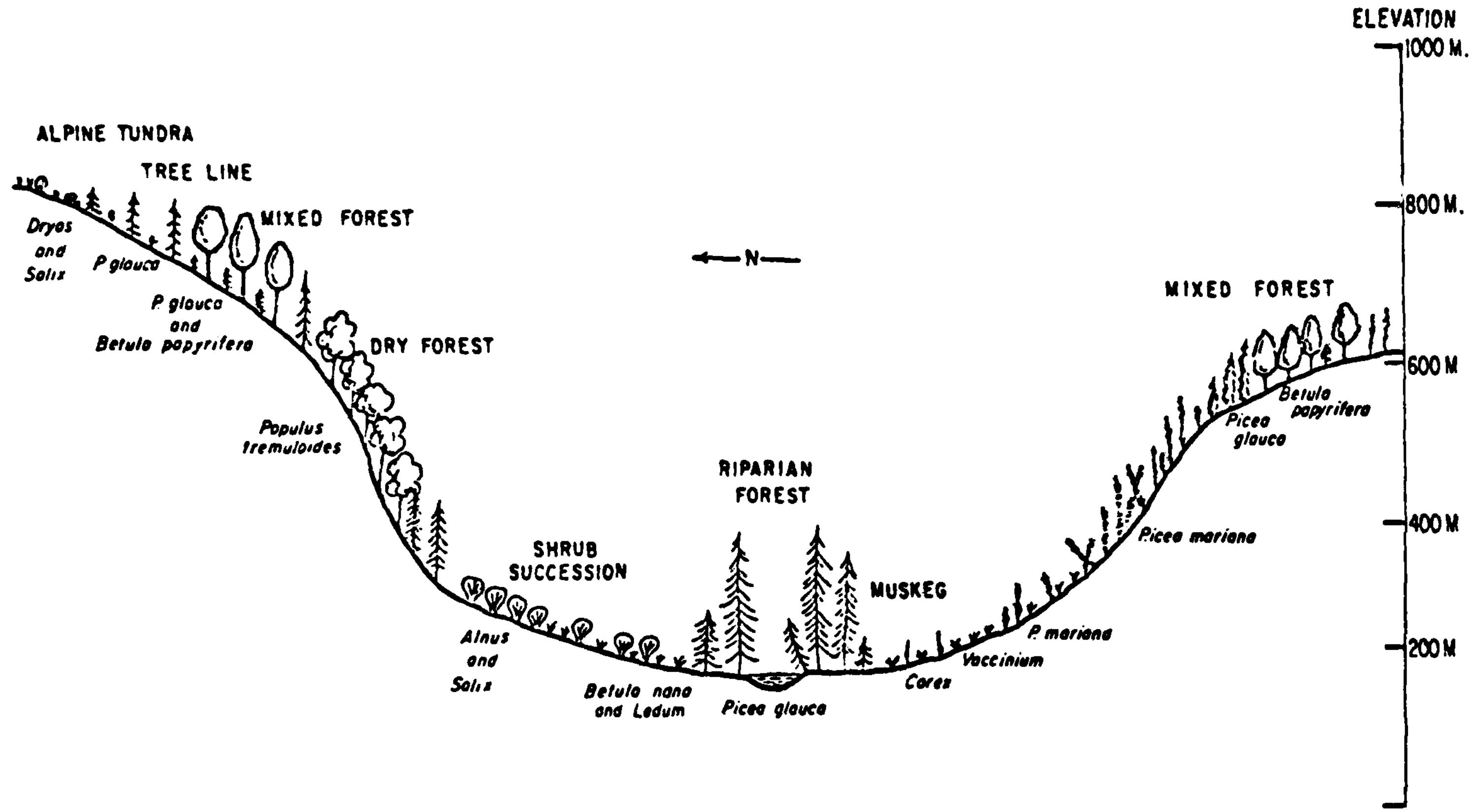


Figure 22. Diagram of vegetation types along a topographic gradient in Interior Alaska. (From Johnson and Vogel, 1966, figure 32, p. 41.)

acutiflorum, Salix polaris, Stellaria monantha, and Tomenthypnum nitens.

Viereck, 1963

On north-facing slopes in the Alaska Range small, open stands of spindling black spruce occur with a shrub layer of alder, willow, and Labrador tea. The ground cover consists mostly of a mat of Sphagnum spp. and other mosses. At higher elevations (3000-4000 ft) a shrub-sedge-moss type is found. It consists of scattered shrubs of alder and willow, between and under which is a hummocky mat of Sphagnum spp. and other mosses, Ledum, birch, and Carex bigelowii and only an occasional low individual black spruce.

Viereck, 1970

[Plant succession along braided and meandering streams in Interior Alaska is diagrammatically shown in figure 23.] Colonization of freshly formed alluvium is by light-seeded herbs and shrubs, primarily Salix species. These shrubs grow rapidly and are flooded almost every spring but are able to send out adventitious roots and continue to grow. Within 10 to 15 years balsam poplars, established at the same time as the willows, overtop the shrubs and begin to shade them. By the time the balsam poplars are 50 years old, the shrub layer of willows has been replaced by Rosa acicularis and Viburnum edule. Seedlings of white spruce become established at this stage. The spruce overtop the balsam poplar after 50 to 100 years and gradually eliminate the poplar from the stand. As the white spruce stands mature a thick moss layer forms and may produce an organic layer 20 to 30 cm thick. Permafrost sometimes occurs in these well-insulated

soils; on the older terraces, permafrost is prevalent and close to the surface. Slow-growing black spruce stands become the dominant vegetation. Farther from the river, black spruce stands are often replaced by bogs when some disturbance of the organic layer causes shallow thawing of permafrost. Thawing creates a wet depression suitable for the establishment of bog species.

Viereck, 1973a

On poorly drained sites underlain by permafrost and on north-facing slopes, the dominant forest species is black spruce. In the wettest sites tamarack is associated with the black spruce. Throughout the taiga, forest stands are interspersed with bogs of many types. These bogs vary from the rich grass and sedge types to the oligotrophic *Sphagnum* bogs. A tussock sedge type with *Sphagnum* mosses and low ericaceous shrubs (especially *Ledum groenlandicum* and *Chamaedaphne calyculata*) is common.

The successional sequence in the Alaskan taiga following fire is complex and related to a number of parameters -- slope and exposure, presence or absence of permafrost, available seed source, severity of burn, and the autecological relationships of species. Although there are some elements of chance in the successional patterns after any one forest fire, general patterns recur.

The forest succession on wet poorly drained sites and permafrost sites follows a somewhat different sequence from that on basically dry terrain. Because permafrost is close to the surface of the ground, fire does not penetrate deeply, even though it is hot enough to kill the trees.

Recovery is rapid in these stands by vegetative reproduction of the shrubs, sedges, and grasses that existed in the stands before the fire. Thus, within three or five years, the burned areas may have a nearly continuous cover of Eriophorum spp. and grasses, primarily Calamagrostis and Arctagrostis. At the same time shoots from the roots of Salix spp., Vaccinium uliginosum, and Ledum spp. develop rapidly. Recovery of Sphagnum mosses is slower, and pioneer mosses and liverworts such as Polytrichum spp., Ceratodon purpureus, and Marchantia polymorpha may dominate the moss layers for many years. Since black spruce cones are semiserotinous, tremendous quantities of seed drop to the ground during the first and second summer after a fire. These can quickly germinate and enable rapid replacement of the black spruce type by another very dense black spruce stand. If fire is not repeated, there is often a development of a thick Sphagnum mat, paludification of the site, and eventually the development of open black spruce-Sphagnum stands or, in some cases, open bogs with scattered black spruce, tamarack, and birch, locally termed "muskeg".

Viereck, 1973b

Rare, extreme floods can exert a profound, if infrequent, influence on black spruce forests and bogs underlain by permafrost on low terraces. Flooding of these sites can melt the permafrost directly, or roll back sections of the insulating organic layer of the soil, thus exposing the ice-rich silts beneath. Either of these processes can initiate thermal erosion and can sometimes turn portions of forested land into bogs or ponds.

Viereck and Little, 1972

North of the Alaska Range in the unglaciated areas, bogs occur on old river terraces and outwash, in filling ponds and old sloughs, and occasionally on gentle north-facing slopes. They are common south of the Alaska Range on the fine clay soils formed in former glacial lake basins and on morainal soils within the glaciated area. They are also common in the extensive flats of the lower Yukon and Kuskokwim rivers. The vegetation of these bogs consists of varying amounts of grasses, sedges, and mosses, especially Sphagnum. Often the surface is uneven with string-like ridges. Much of the surface of these bogs is too wet for shrubs, but on the drier peat ridges are a number of heath or ericaceous shrubs, willows, and dwarf birches. A list of woody plants common on these sites is given on page 19.

Williamson and Peyton, 1962

The wet tundra type occupies low, generally flat expanses and has a variable plant cover, usually less than ankle-high. Small ponds with Carex spp., Eriophorum spp., and Juncus spp. dot these lowlands. The lower areas are often covered with dense moss, and Eriophorum spp. and Andromeda polifolia are conspicuous. Higher areas or mounds support woody plants such as Ledum decumbens, Betula nana, and Salix spp. [A cross-sectional diagram of the Iliamna Lake area and the characteristic topographic positions of vegetation types is reproduced as figure 24.]

Riparian gravel bar and cutbank

Hanson, 1958

Salix alaxensis communities form a zone of variable width on gravelly soils adjacent to streams in the Nelchina caribou range. Salix alaxensis dominates, growing from 3 to occasionally 20 ft tall, and S. richardsonii is scattered throughout the stand. Common associated species include Salix reticulata and S. polaris. On slightly higher knolls grasses, including Poa alpina, Calamagrostis canadensis, and Trisetum spicatum, are abundant.

Kessel and Schaller, 1960

A tall brush type occurs along the edges of the Sheenjek River and its tributaries. It is composed mostly of Salix alaxensis, S. hastata, and S. arbusculoides, averaging 10 to 15 ft high, and confined to a 10-to 30-ft-wide strip along each side of the stream.

Scott, 1972

The Epilobium latifolium-Brachythecium turgidum nodum is typical of the sparse vegetation of lower alpine floodplains along the Chitistone River.

The Dryas octopetala-Shepherdia canadensis association is typical of the more recent surfaces of the Frederika outwash. Other common species are Dicranum elongatum, Salix reticulata, and seedlings of Salix alaxensis and Populus balsamifera. Another association on outwash is composed of Salix alaxensis, Shepherdia canadensis, and Cladonia pyxidata.

Viereck, 1962

Stands of several species of willow, including *Salix glauca*, *S. richardsonii*, and *S. pulchra*, occur commonly along drainages and in wet protected sites in the alder zone of the Tonzona River.

Viereck, 1963

On areas of gravel alluvium along Dry Creek and its tributaries, extensive stands of *Salix alaxensis* are found. The willows form such a dense canopy in some areas that few plants, except a thick layer of mosses, exist under the shrubs.

In moist, protected gulleys on both north- and south-facing slopes where snow accumulates in the winter there are dense stands of several different species of willows, primarily *Salix alaxensis*, *S. pulchra*, *S. glauca*, and *S. richardsonii*, commonly 3 to 6 ft in height.

Williamson and Peyton, 1962

The riparian woodland type is quite variable in structure. Willow thickets up to 10 ft in height border tundra streams entering Iliamna Lake. On the banks of major streams alder, cottonwood, and scattered individuals of white spruce and paper birch join the willows. Low willows and alders, along with dwarf birch, form a dense understory along many streams.

Vegetation maps

Drury (1956) presented the following vegetation maps of the upper Kuskokwim River area:

Upper Kuskokwim River Region (figure 1, p. 3)

Portion of a lowland near McGrath (figure 19, p. 42)

Detail of a bog ridge and hollow area (figure 19, p. 49)

Johnson and Vogel (1966) have mapped portions of the Yukon Flats (figure 20, p. 28; figure 21, p. 29; figure 23, p. 31; figure 24, p. 32; figure 25, p. 32).

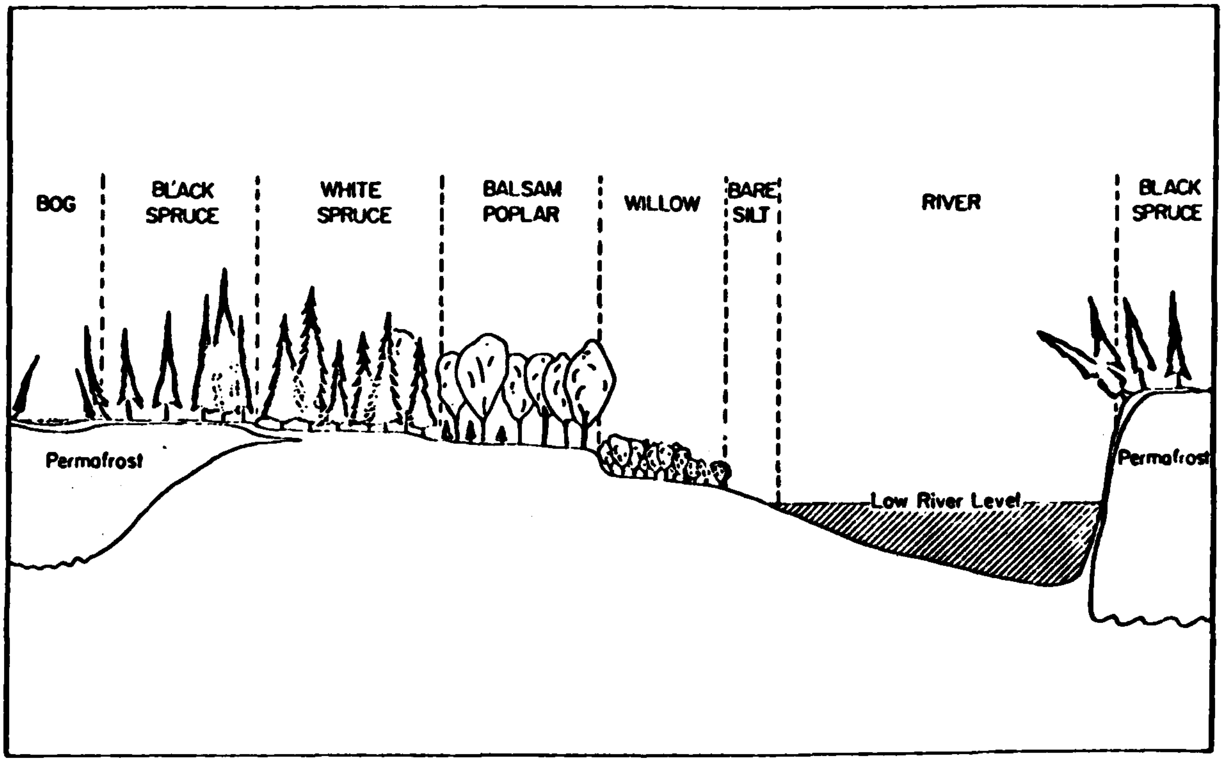


Figure 23. Diagrammatic cross section of typical distribution of vegetation and permafrost across a meander of a river in Interior Alaska. (From Viereck, 1970, figure 3, p. 225.)

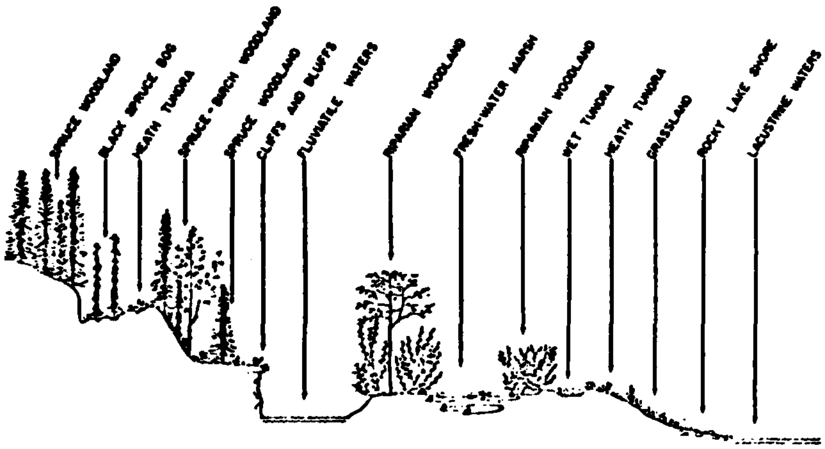


Figure 24. Diagrammatic profile of the Iliamna Lake area showing topography and ecologic formations. (From Williamson and Peyton, 1962, figure 4, p. 9.)

REFERENCES

Amundsen, C. C. 1972. Amchitka Bioenvironmental Program: Plant Ecology of Amchitka Island, Final Report. Battelle, Columbus Laboratories, under AEC Prime, Contract No. AT (26-1)-171. 27 p.

Amundsen, C. C. and E. E. C. Clebsch. 1971. Dynamics of the terrestrial ecosystem vegetation of Amchitka Island, Alaska. Bioscience 21:619-623.

Andersson, M. 1973. Birds of Nuvagapak Point, northeastern Alaska. Arctic 26(3):186-197.

Bank, T. P., II. 1951. Botanical and ethnobotanical studies in the Aleutian Islands I. Aleutian vegetation and Aleut culture. Michigan Acad. Sci., Arts, and Letters Papers 37:13-30.

Bliss, L. C. and J. E. Cantlon. 1957. Succession on river alluvium in northern Alaska. Amer. Midl. Nat. 58:425-469.

Bos, G. N. 1967. Range types and their utilization by muskox on Nunivak Island, Alaska: a reconnaissance study. Univ. Alaska M.S. Thesis. 124 p.

Brandt, H. 1943. Alaska Bird Trails. The Bird Research Foundation, Cleveland, Ohio. 464 p.

Britton, M. E. 1967. Vegetation of the arctic tundra, p. 67-130. In Hansen, H. P. ed., Arctic Biology. 2nd ed. Oregon State University Press, Corvallis.

Brown, J., F. A. Pitelka, and H. N. Coulombe. 1970. A word model of the Barrow ecosystem, p. 41-43. In Fuller, W. A. and P. G. Kevan, eds., Proceedings of the Conference on Productivity and Conservation in Northern Circumpolar Lands. International Union for Conservation of Nature and National Resources, Morges, Switzerland.

Burns, J. J. 1964. The ecology, economics, and management of mink in the Yukon-Kuskokwim Delta, Alaska. Univ. of Alaska M.S. thesis. 114 p.

Cantlon, J. E. 1961. Plant cover in relation to macro-, meso-, and micro-relief; final report. Arctic Institute of North American and Arctic Research Laboratory Grant ONR-208, 212. 76 p.

Childs, H. E., Jr. 1969. Birds and mammals of the Pitmegea River region, Cape Sabine, northwestern Alaska. Biol. Pap. Univ. Alaska No. 10. 76 p.

Churchill, E. D. 1955. Phytosociological and environmental characteristics of some plant communities in the Umiat region of Alaska. Ecology 36(4):606-627.

Clebsch, E. E. C. 1957. The summer season climatic and vegetational gradient between Point Barrow and Meade River, Alaska. Univ. Tennessee M.S. thesis. 60 p.

Cooper, W. S. 1931. A third expedition to Glacier Bay, Alaska. Ecology 12:61-95.

Cooper, W. S. 1936. The strand and dune flora of the Pacific Coast of North America: a geographic study, p. 141-184. In Essays in Geobotany, Univ. of California Press, Berkeley.

Cooper, W. S. 1939. A fourth expedition to Glacier Bay, Alaska. Ecology 20:130-155.

Cooper, W. S. 1942. Vegetation of the Prince William Sound region, Alaska, with a brief excursion into post-Pleistocene climatic history. Ecol. Monogr. 12:1-22.

Craig, P. C. and P. J. McCart. 1975. Classification of stream types in Beaufort Sea drainages between Prudhoe Bay and the MacKenzie Delta, N.W.T., Canada. Arctic and Alpine Research 7:183-198.

Crow, J. H. 1968. Plant ecology of the Copper River Delta, Alaska. Washington State Univ. Ph.D. thesis. 120 p.

Dachnowski-Stokes, A. P. 1941. Peat resources in Alaska. U.S. Dept. Agr. Tech. Bull. No. 769. 84 p.

Dean, F. C. and D. L. Chesemore. 1974. Studies of birds and mammals in the Baird and Schwatka Mountains, Alaska. Biol. Pap. Univ. Alaska No. 15. 80 p.

Decker, H. F. 1966. Plants, p. 73-95. In Goldthwait, R. P. et al. Soil Development and Ecological Succession in a Deglaciated Area of Muir Inlet, Southeast Alaska. Institute of Polar Studies Report No. 20, Ohio State Univ. Research Found., Columbus.

Dennis, J. 1969. Growth of tundra vegetation in relation to arctic microenvironments at Barrow, Alaska. Duke Univ. Ph.D. thesis. 289 p.

Drew, J. V. and R. E. Shanks. 1965. Landscape relationships of soils and vegetation in the forest-tundra ecotone, upper Firth River Valley, Alaska-Canada. Ecol. Monogr. 35:285-306.

Drury, W. H., Jr. 1956. Bog flats and physiographic processes in the upper Kuskokwim River region, Alaska. Harvard Univ. Contrib. Gray Herb. 178. 130 p.

Fay, F. H. and T. J. Cade. 1959. An ecological analysis of the avifauna of St. Lawrence Island, Alaska. Univ. California Publ. Zool. 63:73-150.

Griggs, R. F. 1936. The vegetation of the Katmai District. Ecology 17:380-417.

Hakala, J. B. 1952. The life history and general ecology of the beaver (Castor canadensis Kuhl) in interior Alaska. Univ. of Alaska M.S. thesis. 181 p.

Hanson, H. C. 1950. Vegetation and soil profiles in some solifluction and mound areas in Alaska. Ecology 31:606-630.

Hanson, H. C. 1951. Characteristics of some grassland, marsh, and other plant communities in western Alaska. Ecol. Monogr. 21:317-378.

Hanson, H. C. 1953. Vegetation types in northwestern Alaska and comparisons with communities in other arctic regions. Ecology 34:111-140.

Hanson, H. C. 1958. Analysis of Nelchina Caribou Range. U.S.D.I. Fish and Wildlife Service, Federal Aid in Wildlife Job Completion Report, Job 6, W-3-R-12, Juneau, Alaska. 68 p.

Harris, A. S. et al. 1974. The forest ecosystem of southeast Alaska, I. The setting. U.S. Dept. Agr. Forest Service General Technical Report PNW-12, Portland. 40 p.

Harvill, A. M. 1948. A phytogeographic study of Alaskan mosses. Univ. Michigan Ph.D. thesis. 337 p.

Heilman, P. E. 1966. Change in distribution and availability of nitrogen with forest succession in interior Alaska. Ecology 47:825-831.

Heinselman, M. L. 1963. Forest sites, bog processes, and peatland types in the Glacial Lake Agassiz Region, Minnesota. Ecol. Monogr. 133:327-374.

Heusser, C. J. 1960. Late-Pleistocene environments of North Pacific North America. American Geographical Society Special Publication No. 35. 308 p.

Hopkins, D. M. and R. S. Sigafoos. 1951. Frost action and vegetation patterns on Seward Peninsula, Alaska. U.S. Geol. Surv. Bull. 974-C, pp 51-100.

Hultén, E. 1960. Flora of the Aleutian Islands. 2nd ed. J. Cramer, Weinheim. 376 p.

Hultén, E. 1962. Flora and vegetation of Scammon Bay, Bering Sea Coast, Alaska. Svensk. Bot. Tidsk. 56:36-54.

Hultén, E. 1966. Contributions to the knowledge of flora and vegetation of the southwestern Alaskan mainland. Svensk. Bot. Tidsk. 61:175-189.

Hultén, E. 1968. Flora of Alaska and neighboring territories. Stanford Univ. Press, Stanford. 1008 p.

Hultén, E. 1973. Supplement to flora of Alaska and neighboring territories, a study in the flora of Alaska and the transberingian connection. Bot. Not. 126:459-512.

Isleib, M. E. and B. Kessel. 1973. Birds of the North Gulf Coast-Prince William Sound region, Alaska. Biol. Pap. Univ. Alaska No. 14. 149 p.

Johnson, A. W., L. A. Viereck, R. E. Johnson, and H. Melchior. 1966. Vegetation and flora of the Cape Thompson-Ogotoruk Creek area, Alaska, p. 277-354. In Wilimovsky, N. J. and J. N. Wolfe eds., Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Commission, Division of Technical Information, PNE-481.

Johnson, P. L. and T. C. Vogel. 1966. Vegetation of the Yukon Flats region, Alaska. U.S. Army Materiel Command, CRREL Res. Rep. 209. 53 p.

Johnson, P. L. and L. L. Tieszen. 1973. Vegetative research in arctic Alaska, p. 169-198. In Britton, M. E., ed., Alaskan Arctic Tundra. Arctic Inst. North America Tech. Paper No. 25.

Johnson, P. R. and C. W. Hartman. 1969. Environmental Atlas of Alaska. Inst. Arctic Environ. Eng., Inst. Water Res., Univ. Alaska, Fairbanks. 111 p.

Kessel, B. and T. J. Cade. 1958. Birds of the Colville River, northern Alaska. Biol. Pap. Univ. Alaska No. 2. 83 p.

Kessel, B. and G. B. Schaller. 1960. Birds of the upper Sheenjek Valley, northeastern Alaska. Biol. Pap. Univ. Alaska No. 4. 59 p.

Klein D. R. 1958. Saint Matthew Island reindeer-range studies. USDI Fish and Wildlife Service, Federal Aid in Wildlife Job Completion Report, Project W-3-R-12, Work plan B, Job No. 6. Juneau, Alaska. 39 p.

Klein, D. R. 1965. Ecology of deer range in Alaska. Ecol. Monogr. 35: 259-284.

Koranda, J. J. 1960. The plant ecology of the Franklin Bluffs area, Alaska. Univ. Tennessee Ph.D. thesis. 234 p.

Koranda, J. J. 1973. The North Slope, its physiography, fauna, and its flora. Alaska Geographic 1:6-37.

Koranda, J. J. and C. D. Evans. 1975. A discussion of sites recommended as potential natural landmarks in the Arctic Lowland Natural Region, northern Alaska. Tundra Biome Center, Univ. Alaska, Fairbanks. 189 p.

Lawrence, D. B. 1958. Glaciers and vegetation in southeastern Alaska. Am. Sci. 46:89-122.

Lutz, H. J. and A. P. Caporaso. 1958. Indicators of forest land classes in airphoto interpretation of the Alaska interior. U.S. Forest Service, Alaska For. Res. Cent. Stn. Pap. 10. 31 p.

McRoy, C. P. 1968. The distribution and biogeography of Zostera marina (eelgrass) in Alaska. Pacific Sci. 22:507-513.

Meehan, W. R. 1974. The forest ecosystem in southeast Alaska, 4. Wildlife habitats. U.S. Dept. Agr. For. Serv. Gen. Tech. Report PNW-16, Portland. 32 p.

Melchior, H. R. 1973. Biological survey of the Kobuk Sand Dunes. Chukchi-Imuruk biological survey interior report, manuscript. Cooperative Park Studies Unit, Univ. Alaska, Fairbanks. 14 p.

Melchior, H. R. and C. H. Racine. 1974. Kobuk National Monument biological survey, second interim report, manuscript. Cooperative Park Studies Unit, Univ. Alaska, Fairbanks. 14 p.

Merriam, C. H. 1892. Plants of the Pribilof Islands, Bering Sea. Proc. Biol. Soc. Wash. 7:133-150.

Moore, P. D. and D. J. Bellamy. 1974. Peatlands. Springer-Verlag, New York. 221 p.

Neiland, B. J. 1971. The forest-bog complex of Southeast Alaska. Vegetatio 22:1-64.

Neiland, B. J. and J. R. Hok. 1975. Vegetation of the Prudhoe Bay region, p. 73-78. In Brown, J. ed., Ecological Investigations of the Tundra Biome in the Prudhoe Bay region, Alaska. Biol. Pap. Univ. Alaska Special Report No. 2.

Orth, D. J. 1967. Dictionary of Alaska place names. U.S. Geol. Surv. Paper 567. 1084 p.

Palmer, L. J. 1942. Major vegetative types of southeastern Alaska. USDI Fish and Wildlife Service Report. Juneau, Alaska. 16 p.

Palmer, L. J. and C. H. Rouse. 1945. Study of the Alaska tundra with reference to its reactions to reindeer and other grazing. USDI Fish and Wildlife Service, Research Report 10. 48 p.

Pegau, R. E. 1968. Reindeer range appraisal in Alaska. Univ. Alaska M.S. thesis. 130 p.

Porsild, A. E. 1939. Contributions to the flora of Alaska. Rhodora 41: 141-301.

Porter, S. C. 1966. Pleistocene geology of Anaktuvuk Pass, Central Brooks Range, Alaska. Arctic Inst. North America Tech. Pap. No. 18. 100 p.

Potter, L. D. 1972. Plant ecology of the Walakpa Bay area, Alaska. Arctic 25:115-130.

Racine, C. H. 1974. Vegetation of the Chukchi-Imuruk area. Chukchi-Imuruk biological survey, manuscript. Cooperative Park Studies Unit, Univ. Alaska, Fairbanks.

Rausch, R. L. and V. R. Rausch. 1968. On the biology and systematic position of Microtus abbreviatus Miller, a vole endemic to the St. Matthew Island, Bering Sea. Z. f. Säugetierkunde 33:65-99.

Rigg, G. B. 1937. Some raised bogs of Southeastern Alaska with notes of flat bogs and muskeg. Am. J. Bot. 24:194-198.

Schamel, D. L. 1974. The breeding biology of the Pacific Eider (Somateria mollissima v-nigra Bonaparte) on a barrier island in the Beaufort Sea, Alaska. Univ. Alaska M.S. thesis. 95 p.

Scott, R. W. 1972. Ecology and phytogeography of alpine vegetation in the southeastern Wrangell Mountains, Alaska. Univ. Michigan Ph.D. thesis. 314 p.

Scott, R. W. 1974a. Soils and patterned ground in the Chitistone Pass region of Alaska, p. 279-282. In Bushnell, V. C. and M. G. Marcus eds., Icefield Ranges Research Project, Scientific Results; Vol. 4. Am. Geogr. Soc.

Scott, R. W. 1974b. Alpine plant communities of the southeastern Wrangell Mountains, Alaska, p. 283-306. In Bushnell, V. C. and M. G. Marcus eds., Icefield Ranges Research Project, Scientific Results: Vol. 4. Am. Geogr. Soc.

Scott, R. W. 1974c. The effect of snow duration on alpine plant community composition and distribution, p. 307-318. In Bushnell, V. C. and M. G. Marcus eds., Icefield Ranges Research Project, Scientific Results: Vol. 4. Am. Geogr. Soc.

Scott, R. W. 1974d. The vegetation of Chitistone, Skolai, and Frederika Valleys, Alaska, p. 331-337. In Bushnell, V. C. and M. G. Marcus eds., Icefield Ranges Research Project, Scientific Results: Vol. 4. Am. Geogr. Soc.

Sellmann, P. V. and J. Brown. 1973. Stratigraphy and diagenesis of perennially frozen sediments in the Barrow region, Alaska, p. 171-181. In Permafrost: The North American Contribution to the Second International Conference. Nat. Acad. Sci., Washington.

Shacklette, H. T. 1961. Substrate relationships of some bryophyte communities on Latouche Island, Alaska. Bryologist 64:1-16.

Shacklette, H. T. 1965a. A leafy liverwort hydrosere on Yakobi Island, Alaska. Ecology 46:377-378.

Shacklette, H. T. 1965b. Bryophytes associated with mineral deposits and solutions in Alaska. U.S. Geol. Surv. Bull. 1198-C. 17 p.

Shacklette, H. T. et al. 1969. Vegetation of Amchitka Island, Aleutian Islands, Alaska. U.S. Geol. Surv. Prof. Pap. 648. 66 p.

Smith, D. K. 1974. Floristic, ecologic, and phytogeographic studies of the bryophytes in the tundra around Barrow, Alaska. Univ. Tennessee Ph.D. thesis. 191 p.

Spetzman, L. A. 1951. Plant geography and ecology of the Arctic Slope of Alaska. Univ. Minnesota M.S. thesis. 186 p.

Spetzman, L. A. 1959. Vegetation of the Arctic Slope of Alaska. U.S. Geol. Surv. Prof. Pap. 302-B. 58 p.

Stephens, F. R. and R. F. Billings. 1967. Plant communities of a tide-influenced meadow on Chichagof Island, Alaska. Northwest Sci. 41:178-183.

Stephens, F. R., C. R. Gass, and R. F. Billings. 1970. The muskegs of Southeast Alaska and their diminished extent. Northwest Sci. 44:123-130.

Stevens, M. E. 1965. Relation of vegetation to some soils in Southeastern Alaska, p. 167-180. In Youngberg, C. T., ed., Forest-soil Relationships in North America. Oregon State Univ. Press, Corvallis.

Streveler, G. P. and B. B. Paige. 1971. The natural history of Glacier Bay National Monument, Alaska. U.S. Dept. Interior, Nat. Park Serv., Glacier Bay National Monument. 89 p.

Streveler, G. P., I. A. Worley, C. J. Terry, and R. J. Gordon. 1973. Dixon Harbor biological survey, final report on the summer phase of 1973 research. Nat. Park Serv. Glacier Bay. 241 p.

Taylor, R. F. 1932. The successional trend and its relation to second-growth forests in Southeastern Alaska. Ecology 13:318-391.

Tedrow, J. C. F. 1973. Pedologic investigations in northern Alaska, p. 93-108. In Britton, M. E. ed., Alaskan Arctic Tundra. Arctic Inst. North America Tech. Pap. No. 25.

Thomas, J. H. 1951. A collection of plants from Point Lay, Alaska. Contrib. Dudley Herb. 4:53-56.

Thomas, J. H. 1957. The vascular flora of Middleton Island, Alaska. Contrib. Dudley Herb. 5:39-56.

Ugolini, F. C. and J. Walters. 1974. Pedological survey of the Noatak River Basin, p. 86-156. In Young, S. B. ed., The Environment of the Noatak River Basin, Alaska. Center for Northern Studies, Wolcott, Vermont.

Viereck, L. A. 1962. Alaska Wildlife Investigations, Sheep and Goat Investigation, Range Survey. Job Completion Report, Research Project Segment, Federal Aid in Wildlife Restoration. Project No. W-6-R-3, Work plan E, Job No. 2-a. 21 p.

Viereck, L. A. 1963. Alaska Wildlife Investigations, Sheep Investigations, Surveys of Range Ecology. Work Plan Segment Report, Federal Aid in Wildlife Restoration. Project No. W-6-R-4, Work plan E, Job No. 2-a.

Viereck, L. A. 1970. Soil temperatures in river bottom stands in Interior Alaska, p. 223-233. In Ecology of the Subarctic Regions, Proceedings of the Helsinki Symposium. UNESCO.

Viereck, L. A. 1973a. Wildfire in the taiga of Alaska. Quat. Research 3:465-495.

Viereck, L. A. 1973b. Ecological effects of river flooding and forest fires on permafrost in the taiga of Alaska, p. 60-67. In Permafrost: The North American Contribution to the Second International Conference. Nat. Acad. Sci., Washington, D. C.

Viereck, L. A. and E. L. Little, Jr. 1972. Alaska trees and shrubs. U.S. Dept. Agr., Forest Service, Agriculture Handbook No. 410. 265 p.

Viereck, L. A. and E. L. Little, Jr. 1975. Atlas of United States trees, Vol. 2. Alaska trees and common shrubs. U.S. Dept. Agr., Forest Service Misc. Publ. No. 1293. 19 p., 105 maps.

Wahrhaftig, C. 1965. Physiographic divisions of Alaska. U.S. Geol. Surv. Prof. Pap. 482. 52 p.

Walker, D. A. and P. J. Webber. 1973. Personal communication, vegetation map IBP study area, Barrow, Alaska.

Walker, E. H. 1945. Plants of the Aleutian Islands, p. 63-71. In Collins, H. B., Jr., A. H. Clark, and E. H. Walker, The Aleutian Islands: Their People and Natural History. Smithsonian Inst. War Background Studies 21, Publ. 3775.

Webber, P. J. and D. A. Walker. 1975. Vegetation and landscape analysis at Prudhoe Bay, Alaska: a vegetation map of the Tundra Biome study area, pp. 81-91. In Brown, J. ed., Ecological Investigations of the Tundra Biome in the Prudhoe Bay Region, Alaska. Biol. Pap. Univ. Alaska Special Report No. 2.

Weller, M. W. 1976. Personal communication and xeroxed materials.

Wiggins, I. L. 1951. The distribution of vascular plants on polygonal ground near Point Barrow, Alaska. Contrib. Dudley Herb. 4:41-56.

Wiggins, I. L. and D. G. MacVicar. 1958. Notes on the plants in the vicinity of Chandler Lake, Alaska. Contrib. Dudley Herb. 5:69-95.

Wiggins, I. L. and J. H. Thomas. 1962. A Flora of the Alaskan Arctic Slope. Arctic Inst. North America Special Publication No. 4. Univ. Toronto Press, Toronto. 425 p.

Williamson, F. S. L. and L. J. Peyton. 1962. Faunal relationships of birds in the Iliamna Lake area, Alaska. Biol. Pap. Univ. Alaska No. 5. 73 p.

Worley, I. A. 1972. The bryo-geography of Southeastern Alaska. Univ. British Columbia Ph.D. thesis. 715 p.

Young, S. B. 1971. The vascular flora of St. Lawrence Island with special reference to floristic zonation in the arctic regions. Harvard Univ. Contrib. Gray Herb. 201. 115 p.

Young, S. B. 1974. Vegetation of the Noatak Valley, Alaska p. 58-84. In Young, S. B. ed., The Environment of the Noatak River Basin, Alaska. Center for Northern Studies, Wolcott.

Zach, L. 1950. A northern climax, forest or muskeg? Ecology 31:304-306.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Batten, Alan R.
A literature survey on the wetland vegetation of Alaska / by Alan R. Batten and David F. Murray (Institute of Arctic Biology and Museum, University of Alaska) . -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from NTIS, 1982.
222 p. ; ill. ; 27 cm. -- (Technical report ; Y-82-2)
Cover title.
"August 1982."
Final report.
"Prepared for Office, Chief of Engineers, U.S. Army under Contract No. DACW39-76-M-2472."
"Monitored by Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station."
Bibliography: p. 214-222.

1. Alaska. 2. Botany--Alaska. 3. Wetlands--Alaska. I. Murray, David F. II. United States. Army. Corps of Engineers. Office of the Chief of Engineers.

Batten, Alan R.
A literature survey on the wetland vegetation : ... 1982.
(Card 2)

III. University of Alaska. IV. U.S. Army Engineer Waterways Experiment Station. Environmental Laboratory. V. Title VI. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; Y-82-2.
TA7.W34 no.Y-82-2